SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

ANNUAL CONVENTION NUMBER

Special Features

Sludge Digestion Studies—Buck et al.

Portland Treatment Plant—Cunningham

Spray Irrigation—Sanborn

Underground Disposal—Henkel

Research Survey—Heukelekian and Wisely

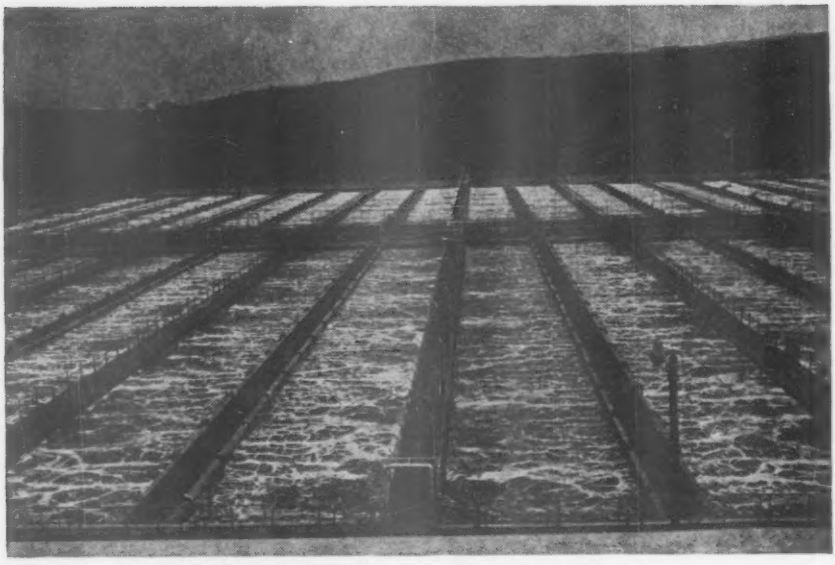
Twenty-Sixth Annual Meeting—Oct. 13–16, 1953
Bayfront Auditorium, Miami, Fla.
(See Page 1120)

SEPTEMBER, 1953—VOL. 25, No. 9

CHICAGO SEWAGE EQUIPMENT

WIDE-BAND AIR DIFFUSION SYSTEMS

For Maximum Effectiveness of Sewage Aeration



Aeration Tanks at Hyperion Sewage Treatment Plant, Los Angeles, California
The City of Los Angeles, Board of Public Works
and Metcalf & Eddy, Engineers

Chicago Pump Company Air Diffusion Equipment provides maximum effectiveness and efficiency through use of the Wide-Band Aeration System. To obtain the maximum purification power of conventional activated sludge or any of its variations, air distribution to satisfy the oxygen demand is required. The flexibility of air distribution in the Wide-Band Aeration System permits design application and field adjustment to satisfy this oxygen demand throughout the aeration system. Highest oxygen absorption with complete cross-sectional circulation provides for maximum treatment control with economical use of air.

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Wide-Band aeration has demonstrated its effectiveness for channel aeration and pre-aeration, to accomplish grit removal, grease removal, odor control, and reduction of high chemical oxygen demands either in single or separate tank structures for pre-treatment. To provide complete responsibility for "air to water" aeration, Chicago Pump Company has developed equipment and application standards for blowers, filters, air main piping and metering.

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SEWAGE EQUIPMENT DIVISION

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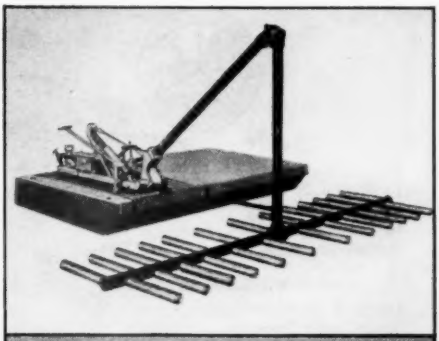

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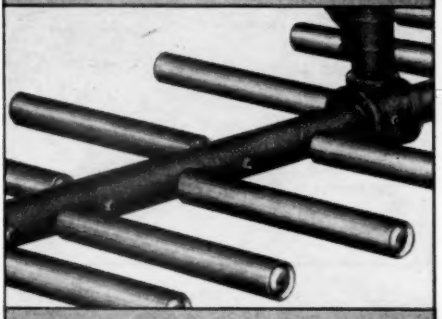

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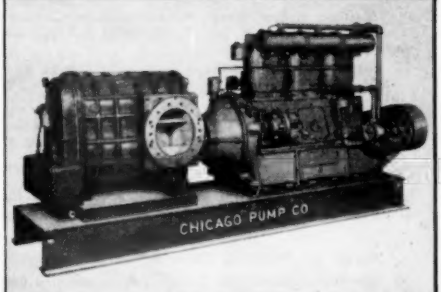

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SEWAGE AND INDUSTRIAL WASTES

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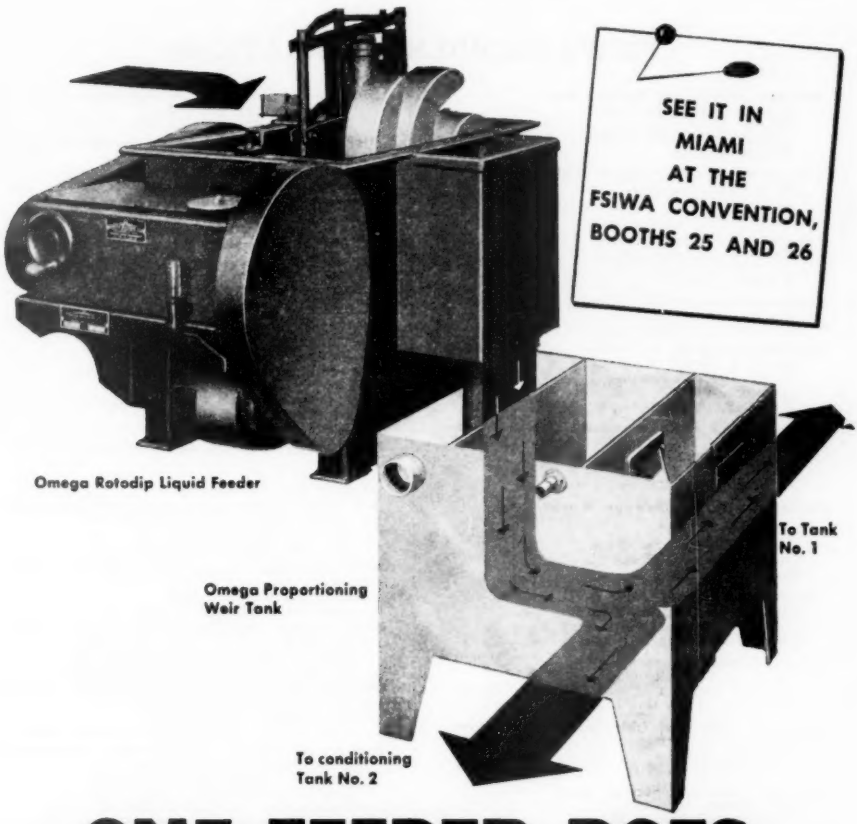

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Cleaning valves at main and throat keep piezometer openings clear. Special short tubes for insertion in existing lines. Type VE elliptical venturi with *flat* top and bottom for low-velocity flows.

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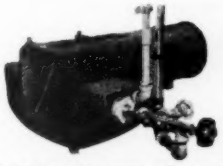

TYPE S PARABOLIC FLUME—Specially designed for measuring sewage and wastes with heavy solids—under low heads! Widely used as indicating device and with Type H Meter for recording and totalizing flow.

Full 20 to 1 flow range with no special approach section. Simple to install. In 6" to 36" standard pipe sizes with flanged, bell or spigot inlet.

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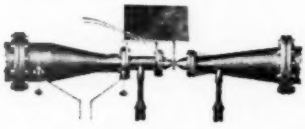

SQUEEZE CONTROLLER—Accurately regulates flow of sewage, sludge, trade wastes. Most accurate primary device, a Simplex venturi tube, has special throat section of *flexible rubber*—measures as it controls!

If flow tends to change, motor-driven clamp adjusts throat . . . quickly returns flow to control point. Viscous flows contact no moving parts in self-scouring throat.

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TYPE H METER
Gives ±2% accuracy at any point over flow ranges up to 13 to 1. Indicates, records, totalizes. Used with venturi tubes, flumes, weirs for measuring sewage, sludge, trade wastes.

Circular chart gradations evenly spaced for easy reading. Available for wall, panel or floor stand mounting.

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TYPE MO METER—Most accurate inferential type instrument. Measures within ±2% over ranges up to 20 to 1 using venturi tube, flow nozzle or orifice plate. Adaptable to measurement over a 32½ to 1 range.

Evenly spaced rectangular chart is easy to read. Wall, panel or floor stand mounting—for high or low head sewage, sludge.

WRITE FOR BULLETIN NO. 500

OTHER SIMPLEX PRODUCTS

- Remote Transmission for Measurement and Control
- Chemical Feed Units
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MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Rocky Mountain Sewage Works Association	Hotel La Fonda, Santa Fe, N. M.	Sept. 21, 1953
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Owensboro Hotel, Owensboro, Ky.	Sept. 21–23, 1953
Michigan Sewage and Industrial Wastes Association	Michigan State College, Kellogg Center, East Lansing, Mich.	Sept. 21–23, 1953
South Dakota Water and Sewage Works Conference	Alex-Johnson Hotel, Rapid City, S. Dak.	Sept. 22–24, 1953
Georgia Water and Sewage Association	Georgia Institute of Technology, Atlanta, Ga.	Sept. 23–25, 1953
Missouri Water and Sewerage Conference	Elms Hotel, Excelsior Springs, Mo.	Sept. 27–29, 1953
North Dakota Water and Sewage Works Conference	Leland Parker Hotel, Minot, N. Dak.	Oct. 1–2, 1953

TWENTY-SIXTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
Florida Sewage and Industrial Wastes Association
Municipal (Bayfront Park) Auditorium, Miami, Florida
October 13–16, 1953

Address hotel reservation requests to: FSIWA Convention Housing Bureau, 320 N.E. Fifth Street, Miami, Florida

Canadian Institute on Sewage and Sanitation	General Brock Hotel, Niagara Falls, Ont., Can.	Oct. 26–28, 1953
New England Sewage and Industrial Wastes Association	Wannamoisett Country Club, 96 Hoyt Avenue, East Providence, R. I.	Nov. 5, 1953
Pacific Northwest Sewage and Industrial Wastes Association	Hotel Chinook, Yakima, Washington,	Nov. 5–7, 1953
North Carolina Sewage and Industrial Waste Association	Sheraton Hotel, High Point, N. C.	Nov. 9–11, 1953
Nebraska Sewage and Industrial Wastes Association	Hotel Capital, Lincoln, Nebr.	Nov. 12–13, 1953
Oklahoma Water, Sewage and Industrial Wastes Conference	Okla. A & M College, Stillwater, Okla.	Nov. 16–20, 1953

Briefs from the YEOMANS GUARD

A "Package" Treatment Plant for Every Small Community

Many small communities, outlying schools and housing projects faced the perplexing problem of how to treat small quantities of domestic sewage on a small budget—a problem multiplying rapidly as new residential developments spring up near big cities. Usually the cost of hooking up to the city's treatment plant is prohibitive; and there just hasn't been an efficient low-cost alternative.

Now it's different—

- **Yeomans has developed a series of "package plants" engineered for population groups of 50 up to 2500.**

These plants are compact, simple, efficient, exceedingly economical both as to construction and operation. They require only normal "good housekeeping"—a few minutes a day of a handyman's time. The plant may be of biological trickling filter or activated sludge type—whatever community needs dictate.

The new Yeomans Pkg. Plants Bulletin tells the full story.

Webster-Crestwood Treatment Plant Makes Residence Sites *Worth More Money*

In an attractive wooded spot in rolling St. Louis County, Missouri, is a neat and sightly sewage treatment plant that serves the fast-growing residential subdivisions of Grant Ridge, Elmont Park, Webster Oaks, Webster Ridge and Webster Downs.

This plant is efficient proof that sound and adequate provision for a community's sanitary requirements is a potent factor in making it a desirable place to live.

With admirable foresight, enough property was set aside—about 7 acres—so that the plant, designed for a population of 1600, can be enlarged easily and at moderate cost, to keep pace with population increases; up to an ultimate 20,000 persons.

Heart of the plant—a complete Yeomans installation of the activated sludge type—is a Yeomans "Spiral-flo" Aerator. That simple and dependable mechanism introduces air into the sewage, and disperses the activated sludge flow throughout the whole aeration tank content. Primary and final collection tanks are Yeomans "Streamline" Sludge Collectors; sewage lift is handled by Yeomans Expelsor pneumatic ejectors; and control-house pumps are Yeomans horizontal non-clog sludge pumps.

Treatment in this plant is high in efficiency, and admirably low in cost of operation and maintenance. Straight-wall clarifier design minimized construction costs.

If you want additional data—*well worth attention*—write our Sanitary Engineering Division and mention this item.

Difficult Industrial Wastes Successfully Treated In Yeomans Plants

A number of industrial wastes, including some described as "difficult," are being treated in Yeomans plants—with results described in some instances as "miraculous."

Efficient treatment is the main objective, of course; but the extraordinarily low cost of Yeomans plants—as to both construction and operation—is a factor that is pleasant to consider.

If you have a knotty problem of industrial waste treatment, it makes much sense at absolutely no cost to find out how we may be able to help solve it. Just write a letter.

The Yeomans Guard, published several times a year, is a compendium of news and useful information covering the pumping of materials and the treatment of wastes, both domestic and industrial. We shall be pleased to send you the current issue if you'd care to have it. Ask your local Yeomans Representative—listed in the telephone book yellow pages under "Pumps"—or write direct.

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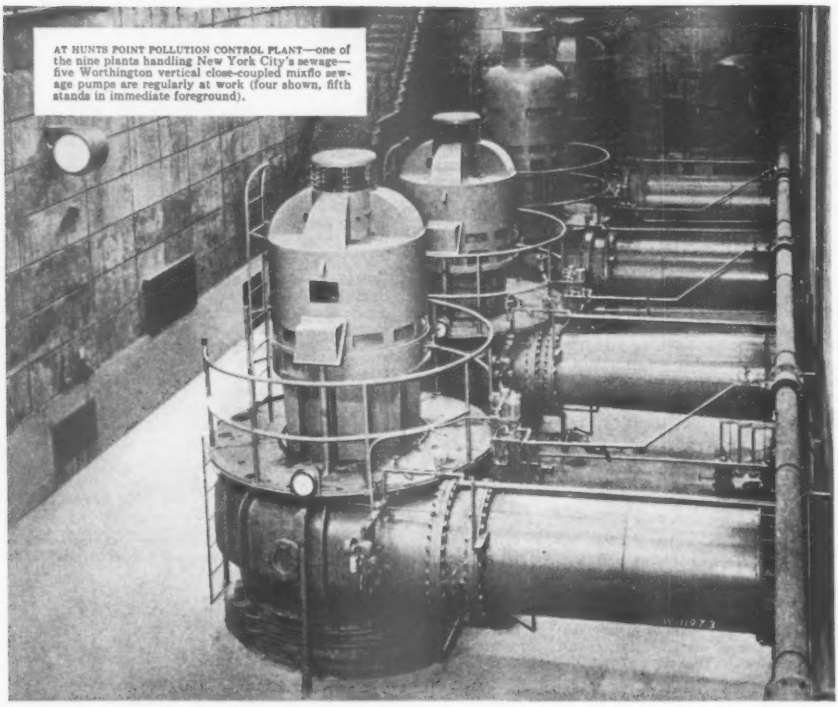

AT HUNTS POINT POLLUTION CONTROL PLANT—one of the nine plants handling New York City's sewage—five Worthington vertical close-coupled mixflo sewage pumps are regularly at work (four shown, fifth stands in immediate foreground).

1689 mgd of New York City's Treated Sewage handled by Worthington pumps

If you want to see Worthington sewage pumps—large and small—at work, you can't go wrong by looking inside six of the nine major disposal plants that serve the City of New York. A total of 1689 mgd installed capacity of Worthington sewage pumps are now in regular use in the world's largest city.

New York's installed capacity of sewage pumps is among the largest in the U. S., so you'd naturally expect the city's public works officials to be familiar with Worthington performance—performance that years ago gave Worthington its position as world leader in the manufacture of pumping equipment.

Hundreds of *smaller* municipalities across the country know Worthington, too, not only for sewage pumps but for water-works pumps, comminutors, engines and other public works equipment. *Worthington Corporation, Public Works Division, Harrison, New Jersey.*

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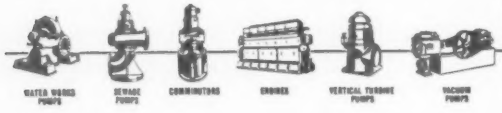

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Public Works Equipment

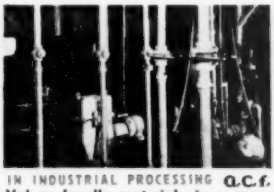
Wedging is impossible

That's just one of the reassuring facts about a.c.f. Full Round Port Cylindrical Plug Valves. The second is simply that you're always assured 100% unobstructed flow at all times.

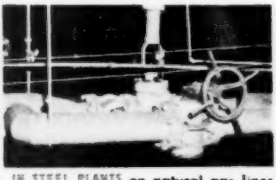
Together they mean long years of trouble-free service handling heavy or viscous ladings, solids in suspension, liquids and gases with equal efficiency.

You can be sure when you specify a.c.f.

IN SEWAGE PLANTS the a.c.f. CYLINDRICAL Plug shears obstructions . . . provides uninterrupted flow on sludge lines.



IN INDUSTRIAL PROCESSING a.c.f. Valves handle materials in suspension, here it's clay slip, with no erosion problems.

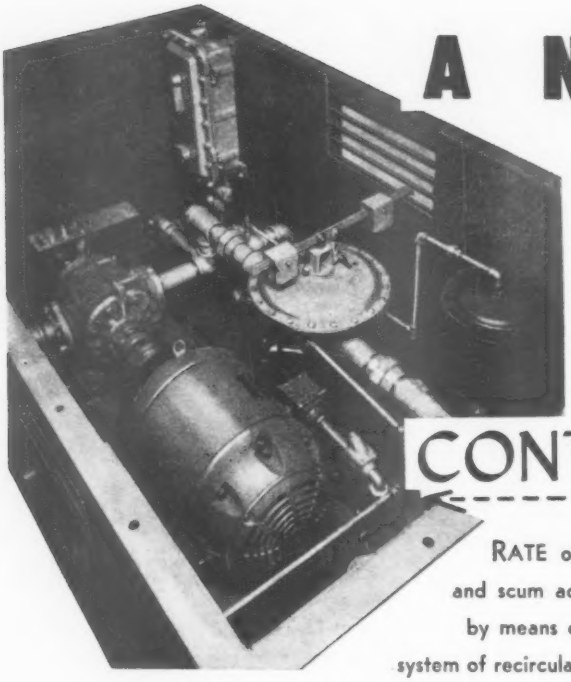


IN STEEL PLANTS on natural gas lines to open hearths, the full pipe area and non-wedging features mean full flow, fast shut-off.

a.c.f. CYLINDRICAL FULL PIPE AREA PLUG VALVES

Write for Catalog 4-SI. American Car and Foundry Company, Valve Division, 1501 E. Ferry Ave., Detroit 11, Michigan.

Representatives in 50 Principal Cities



ANNO

Photo showing assembly of explosion proof compressor and controls in housing mounted on P F T. Floating Cover for P F. T -Pearth Gas Recirculation

Coal Creek Plant
Tulsa, Oklahoma
Water & Sewer Department
City of Tulsa
Engineers

CONTROLLED

RATE of digestion is stepped up and scum accumulations are eliminated by means of this simple and effective system of recirculating gas in sludge digestion tanks. The system is available as an integral part of, or an attachment to the standard P. F. T. Floating Cover, and is also available for use with fixed concrete covered tanks.

The P. F. T. -Pearth Gas Recirculation system as now commercially available was originally developed and patented by the operating staff of the Washington, D. C. Sewage Treatment Plant in an attempt to overcome a difficult scum problem due to an overloaded condition of the digesters. Its merits were demonstrated for more than a year in the full scale operation involving eight of the 84 ft. diameter digesters at that plant.

The system as applied to P. F. T. Floating Covers is now in operation at the Coal Creek plant of the City of Tulsa and will soon be in operation at a number of other sewage treatment plants.

U N C I N G.....

P.F.T.

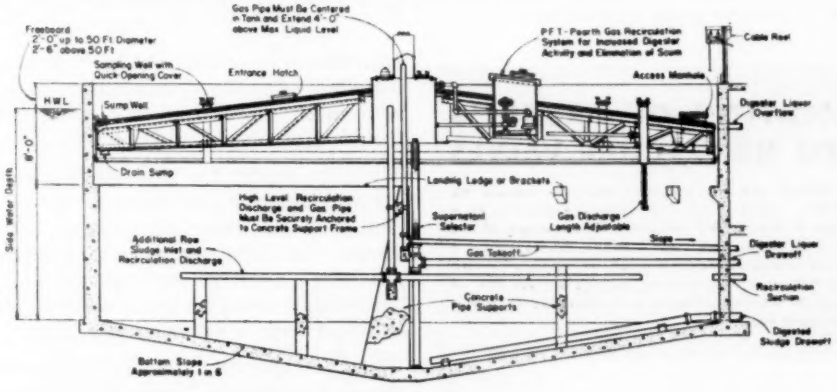
Pearth Gas Recirculation

AS AN ADDED FEATURE OF DIGESTION

GENERAL DETAILS

The recirculation of a relatively small amount of digester gas from the gas collecting dome of a floating cover, to points below the scum level, causes digester liquor to be displaced into the scum zone by the gas lifting action, and agitates the scum while traveling towards the gas collecting dome, causing entrained gas in the scum to be released. With this system there are no moving parts in the digestion tank contents and the problems of clogging, experienced with other devices, are eliminated.

Further information may be obtained from P. F. T. Bulletin 332.

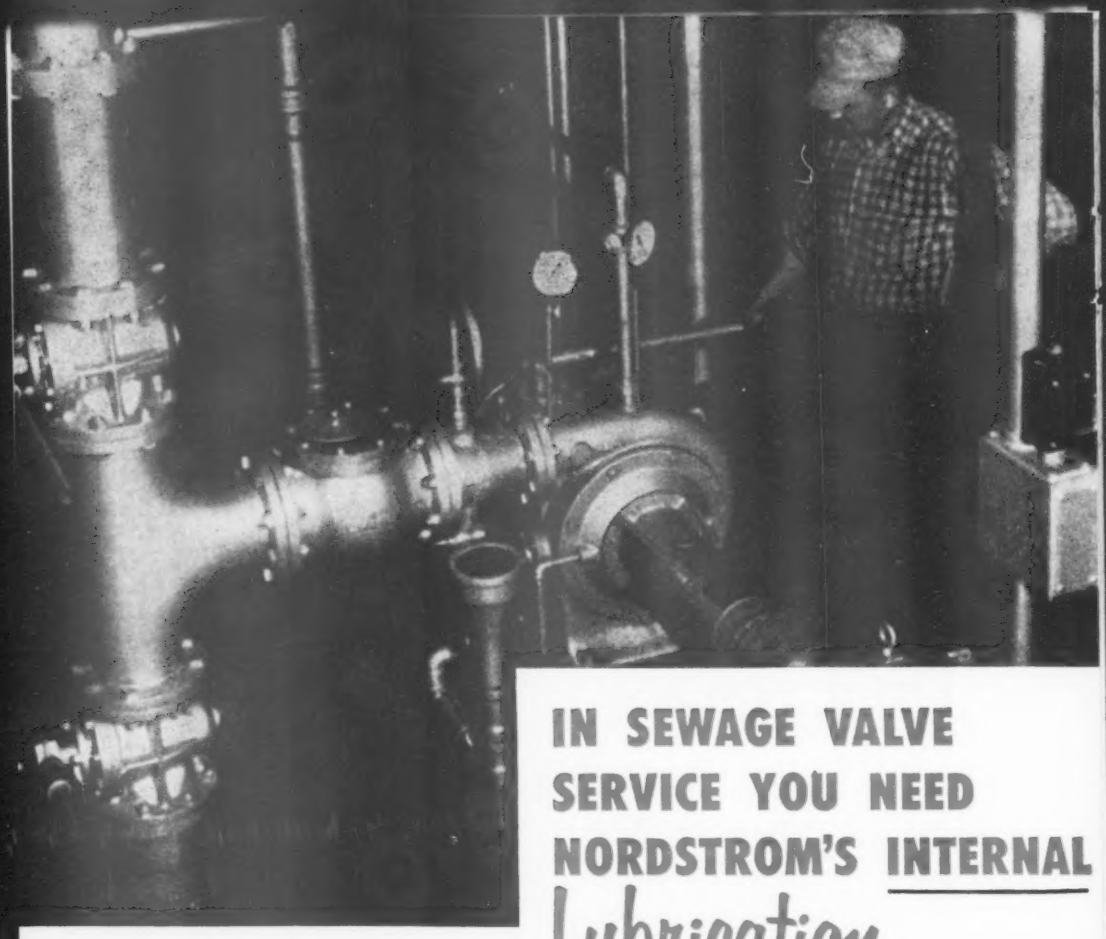

Gas Pipe Must Be Centered in Tank and Extend 4'-0" above Max. Liquid Level
Freeboard 2'-0" up to 50 Ft. Diameter 2'-6" above 50 Ft.
Sampling Well with Quick Opening Cover
Entrance Hatch
P.F.T. - Pearth Gas Recirculation System for Improved Digester Activity and Elimination of Scum
Cable Rail
Access Manhole
H.W.L.
Sump Wall
Digester Liquor Overflow
Side Water Depth 30'-0"
Drain Sump
Landing Ledge or Brackets
High Level Recirculation Discharge and Gas Pipe Must Be Securely Anchored to Concrete Support Frame
Supernatant Selector
Gas Discharge Length Adjustable
Slope
Digester Liquor Drawoff
Additional Raw Sludge Inlet and Recirculation Discharge
Gas Takeoff
Recirculation Suction
Concrete Pipe Supports
Digested Sludge Drawoff
Bottom Slope Approximately 1 in 6

P.F.T. **PACIFIC FLUSH TANK CO.**

Waste Treatment Equipment Exclusively Since 1893

4241 RAVENSWOOD AVE. CHICAGO 13, ILLINOIS

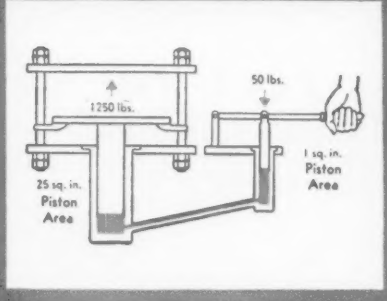
NEW YORK • LOS ANGELES • SAN FRANCISCO • CHARLOTTE, N. C. • JACKSONVILLE • DENVER



Operator closes Nordstrom valve installed on a pump line in a Midwest sewage treatment plant.

APPLICATION OF PASCAL'S LAW TO NORDSTROM VALVES

Nordstrom valves use the scientific principle known as "Pascal's Law", which states that "pressure applied to a confined fluid is transmitted uniformly to all areas of the confining surface." Thus, lubricant pressure developed by a turn of the lubricant screw exerts a powerful "jacking" action on the plug making it easy to turn, spreads a fresh film of lubricant over the seating surfaces, and surrounds each part with a pressurized seal.



IN SEWAGE VALVE SERVICE YOU NEED NORDSTROM'S INTERNAL *Lubrication*

Nordstrom Lubricant-Sealed valves have been installed on sewage treatment lines country-wide with more than a quarter century of trouble-free operation.

There's a reason for Nordstrom's longer valve life and superior performance. All Nordstroms give you the basic advantage of Nordstrom design—an internal lubrication system which provides a positive seal against leakage, protects vital seating surfaces, and keeps the valve ready to operate easily at any time.

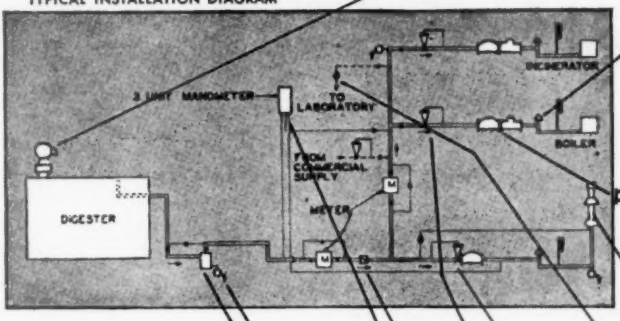
When you specify valves for sewage treatment services, call your Nordstrom representative. His advice will save you time, effort and money. Rockwell Manufacturing Company, Pittsburgh 8, Pennsylvania.

ROCKWELL Built Nordstrom Valves

Lubricant-Sealed for Positive Shut-Off

Another ROCKWELL product

TYPICAL INSTALLATION DIAGRAM



"VAREC" Pressure Relief and Vacuum Breaker Valve with Flame Arrester — Fig. 5800C — Relieves excess pressures and vacuum in digesters and protects vessels from outside fires.

"VAREC" Explosion Relief Valve—Fig. 70 —Relieves sudden surges in pressure from explosion or momentary plant fluctuations.

"VAREC" Flame Trap Assembly—Fig. 450—Prevents flame propagation in piping.

"VAREC" Waste Gas Burner—Fig. 236, 237 or 238—Efficiently burns all excess gas.

"VAREC" Flame Check —Fig. 51A or 52A— Prevents flashback from burner pilot or laboratory burners.

"VAREC" Pressure Relief and Flame Trap Assembly—Fig. 440— Permits excess pressure to be wasted through gas burner and prevents flame flashback from burner.

"VAREC" Pressure Reducing Regulator— Fig. 187 or 387—Controls pressure of gas going to utilization equipment.

"VAREC" Check Valve —Fig. 211 or 211A— Controls direction of gas flow.

"VAREC" Manometer —Fig. 215, 215A, 216 or 216A—Indicates system pressures.

"VAREC" Drip Trap— Fig. 245 or 248.

"VAREC" Sediment Trap — Fig. 230, 232 or 233 — Keeps lines drained and free from moisture.

Plan with "Varec" Symbols of Safety

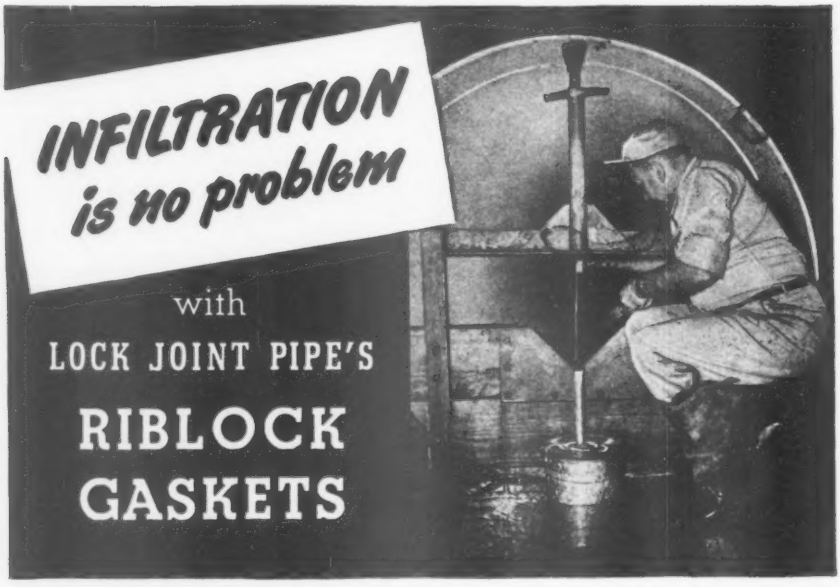
FOR GAS CONTROL THROUGHOUT YOUR SEWAGE TREATMENT PLANT

PROVED and APPROVED "Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY

COMPTON, CALIFORNIA, U. S. A.

S-10 *Available from Authorized Sewage Equipment Agents throughout U. S. and Canada.*



Actual field tests made on pipe laid under severe ground water conditions prove that the problem of infiltration can be overcome by using Lock Joint Reinforced Concrete Sewer Pipe equipped with Riblock Gaskets.

Bogert-Childs Associates, consulting engineers for the enormous Overpeck Sewer Project, conducted a detailed weir test on approximately 7,000 feet of 60" Lock Joint Reinforced Concrete Sewer Pipe with Riblock joints which were installed across the North Jersey swamps and marshlands. This test, which showed only 15 per cent of the volume of infiltration permitted in the specifications, pointed conclusively to the value of Lock Joint sewer pipe and Riblock gaskets for installations of this difficult nature.

For nearly 50 years Lock Joint Pipe Company has been furnishing the most durable and dependable sewer, storm drain, and culvert pipe obtainable. Now, by including Riblock Gaskets in the specifications, you can also assure joints with permanently reliable protection against ground water infiltration.

• • • • •

LOCK JOINT PIPE COMPANY

Established 1905

P. O. Box 269, East Orange, New Jersey

BRANCH OFFICES: Casper, Wyo. • Cheyenne, Wyo. Denver, Col. • Kansas City, Mo. • Valley Park, Mo. Chicago, Ill. • Rock Island, Ill. • Wichita, Kan. Kenilworth, N. J. • Hartford, Conn. • Tucumcari, N. M. Oklahoma City, Okla. • Tulsa, Okla. • Beloit, Wis.

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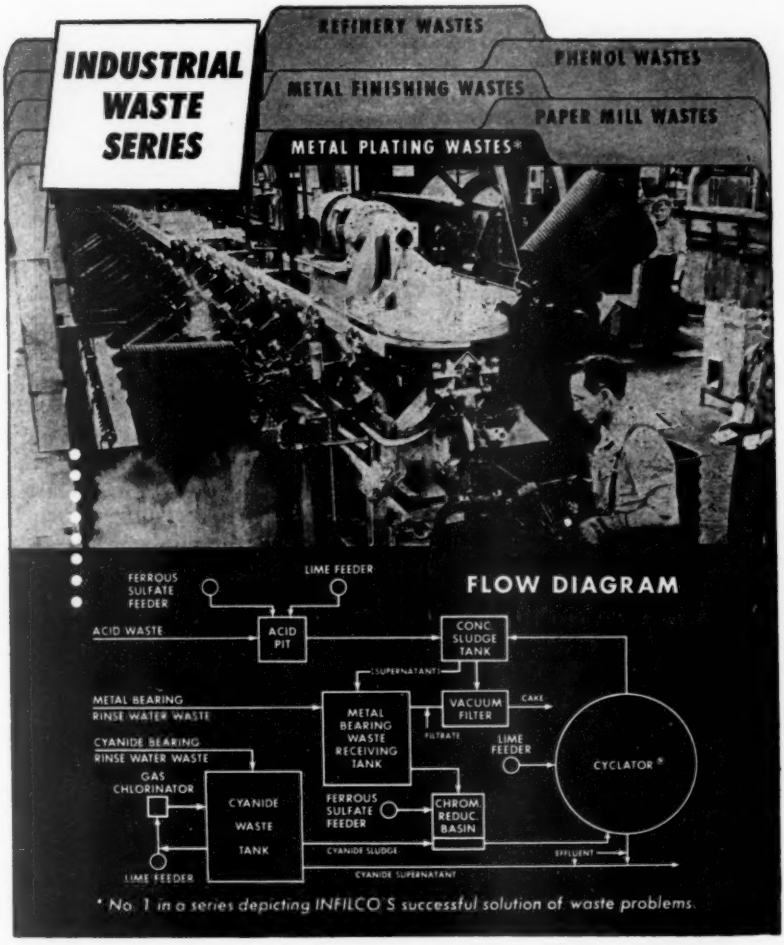


There is no "cure all" for solving waste treatment problems.

FOR EXAMPLE: our thorough evaluation of your problem could dictate the utilization of ion exchange rather than the precipitation equipment found most practical in the existing plating waste installation diagrammed above.

We invite your specific inquiries and know that our wide experience in all phases of waste treatment will prove helpful to you. Request Bulletin 70-S and W-800-S.

INFILCO INC.

Tucson, Arizona

Plants in Chicago and Joliet, Illinois

FIELD OFFICES IN 28 PRINCIPAL CITIES

INFILCO

CHLORINE GAS CONTROL EQUIPMENT

SterElators by Everson

TYPICAL INSTALLATION SHOWING SCALE

METER AND CONTROL CHLORINE GAS IN THE NON CORROSIVE STATE

RATIOS 10 TO 1—50 TO 1—110 TO 1

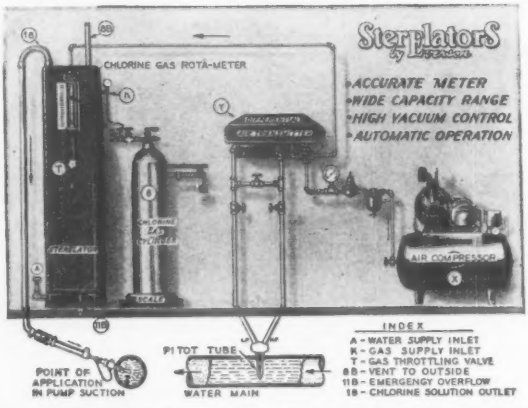
VISIBLE FLOW INDICATION

FOR

WATER WORKS
SEWAGE TREATMENT
INDUSTRIAL PLANTS
SWIMMING POOLS

TYPICAL INSTALLATION WITH BOOSTER PUMP ON WATER SUPPLY

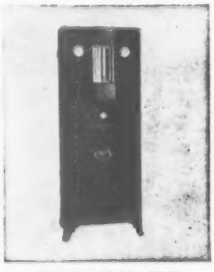
EASY TO OPERATE



LOW MAINTENANCE COSTS

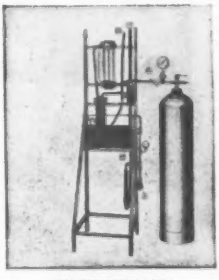
THE EVERSON AIR-O-MATIC SYSTEM

AUTOMATIC PROPORTIONING GAS FEED TO LIQUID FLOW



HIGH CAPACITY R&36

HIGH VACUUM
SOLUTION FEED
DEPENDABLE
ECONOMICAL

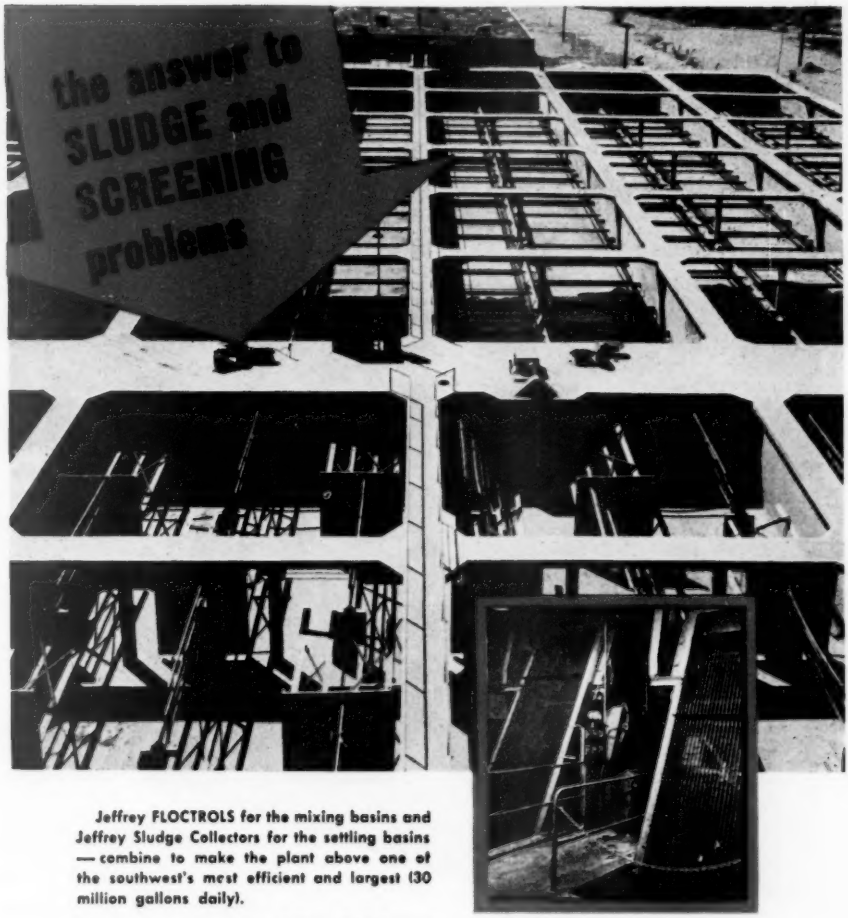


OPEN FRAME MODEL B682

Everson Manufacturing Corporation

207 W. Huron Street Chicago 10, Illinois

REPRESENTATIVES IN PRINCIPAL CITIES



Jeffrey FLOCTROLS for the mixing basins and Jeffrey Sludge Collectors for the settling basins — combine to make the plant above one of the southwest's most efficient and largest (30 million gallons daily).

Insert shows two of four Jeffrey Backcleaned Fine Screens in the 26th Ward Sewage Treatment Works, New York City. Jeffrey pioneered this type of screen, has made many installations in the last eleven years.

Other Jeffrey sanitation equipment includes Grit Washers, Scum Removers, Garbage and Screenings Grinders, Chemical Feeders, Chains, etc.

Ask for Catalog No. 833

THE JEFFREY MANUFACTURING CO.
Columbus 16, Ohio
sales offices and distributors in principal cities
PLANTS IN CANADA, ENGLAND, SOUTH AFRICA

IF IT'S MINED, PROCESSED OR MOVED
. . .IT'S A JOB FOR JEFFREY!

whatever your *Control* problems . . .

IOWA

is ready to meet your every requirement . . .

IOWA Motor Operated Gate Valve . . .
Sewage plant influent

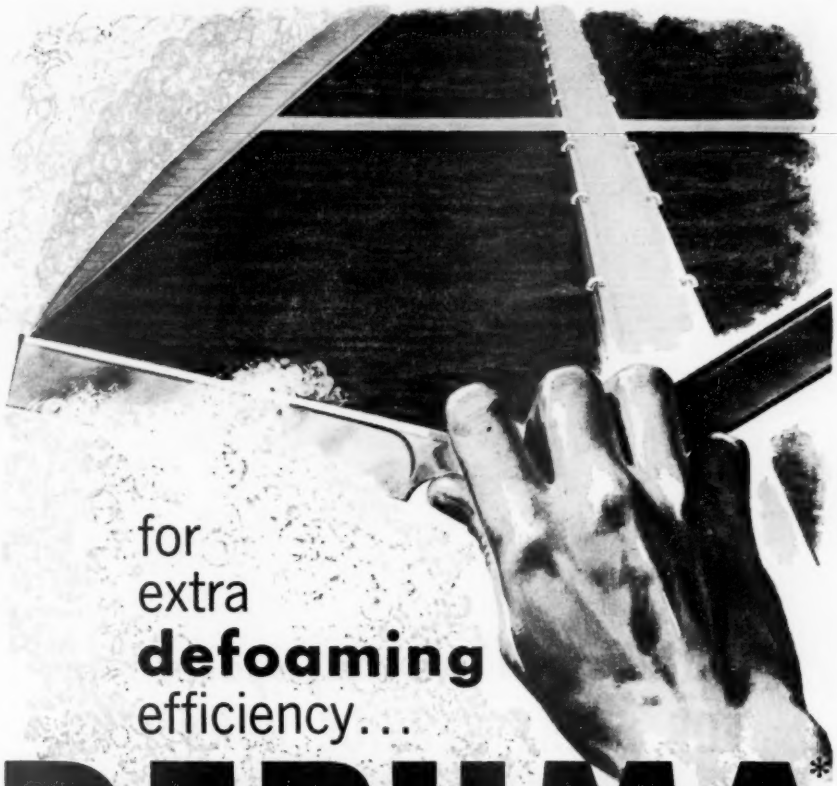
IOWA Gate and Check Valves . . .
Sewage pump discharge

IOWA Manually Operated Sluice Gate . . .
Settling basin drain

IOWA'S complete line of gate valves, check valves, flap valves, shear gates, mud valves and sluice gates is specially designed for severe and particular operating conditions in sewage disposal plants, sewage pumping stations or wherever sewage flow control is required. Let us help you solve your problems. Specify IOWA products and get the best.

IOWA VALVE COMPANY

201-299 N. Talman Ave., Chicago 80, Ill. • *A Subsidiary of James B. Clow & Sons*



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extra
defoaming
efficiency...

DEPUMA*

When foam threatens the efficient operation of aeration tanks or sludge digestion units, rely on DEPUMA for immediate, efficient **antifoam** action. DEPUMA is easy to use and consistently dependable.

For detailed information and free working samples, write to

AMERICAN ANILINE PRODUCTS, INC.
50 Union Square, New York 3, N.Y., Plant: Lock Haven, Pa.

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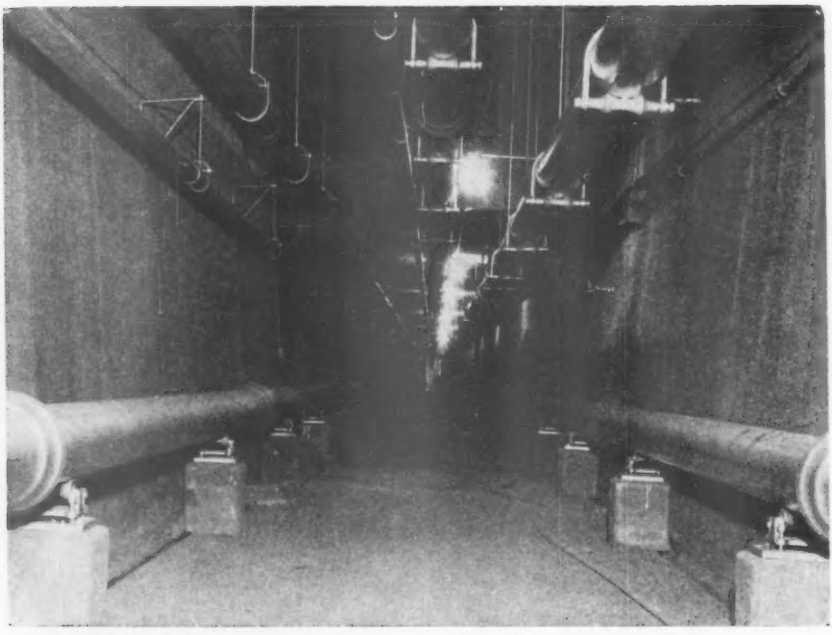


MONO-CAST *Centrifugal Pipe* FOR EVERY SERVICE CONDITION

"Mono-Cast" is the trade name for ACIPCO pipe cast centrifugally in sand-lined molds. Uniform metal section, high physical strength, endurance, and freedom from inclusions are salient properties which have established the name "Mono-Cast" as synonymous with highest quality cast iron pipe. It can be supplied with joints for conveying water, gas, oil, gasoline, sewage, salt brine, ashes—and in fact, just about everything that a pipe line can conceivably convey.

Being cast iron Mono-Cast Pipe enjoys an enviable reputation. Cast iron pipe has had over 300 years of service abroad and more than 100 years of service in the United States. It is satisfactorily serving in locations where especially severe external and internal corrosion conditions exist. Mono-Cast Pipe is designed to give super-service; and its wide acceptance and splendid performance bespeak its excellence and the confidence and esteem in which it is held by those who are using it.

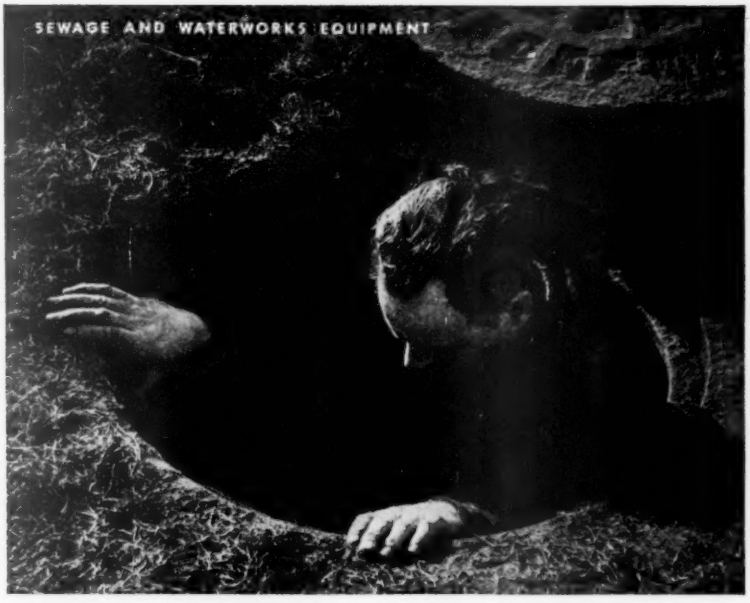
ACIPCO works hand-in-hand with engineers, contractors and superintendents in solving piping problems in their respective fields. Refer your next piping problem to ACIPCO and utilize both our extensive manufacturing facilities and our nearly half a century of experience in furnishing pipe and fittings for water works and sewage disposal plants.

Let us assist you by taking off lists of material and submitting a price on pipe and fittings for your next job.

AMERICAN CAST IRON PIPE COMPANY

BIRMINGHAM 2, ALABAMA

Dallas Houston El Paso Pittsburgh Kansas City New York City
Chicago Minneapolis Cleveland Denver Los Angeles San Francisco Seattle



MANHOLE STEPS:

GIVE THEM AN EXTRA MARGIN OF SAFETY WITH CORROSION-RESISTANT EVERDUR

Manhole steps—of all sewage treatment and waterworks structures—need *extra* corrosion resistance and dependability. Everdur* gives it to them . . . and adds the strength that really pays off . . . in greater safety.

Everdur Copper-Silicon Alloys deliver the same corrosion resistance—*plus ease and economy of operation over the years*—to gates, screens, guides and bolts, weirs, float chambers, troughs, stems and electrical conduit. Everdur is easily fabricated into lightweight, built-up wrought-metal assemblies.

Depending on type or composition, Everdur Alloys can be worked hot or cold. You can form, forge, weld and machine them. They are available in the form of plates, sheets, rods, tubes, electrical conduit and casting ingots.

Write today for Anaconda's free booklet, "Everdur Copper-Silicon Alloys for Sewage Treatment and Waterworks Equipment." For specific help in selecting the right alloy for your equipment, consult our Technical Department. *The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.* 5314BA

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ANACONDA®

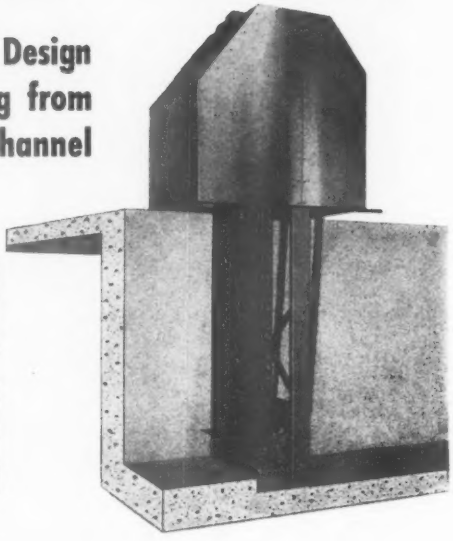
COPPER-SILICON ALLOYS

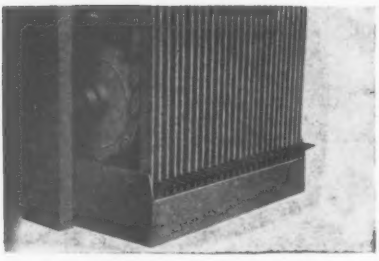
STRONG • WELDABLE • WORKABLE
CORROSION-RESISTANT

COMPLETELY AUTOMATIC MECHANICALLY CLEANED

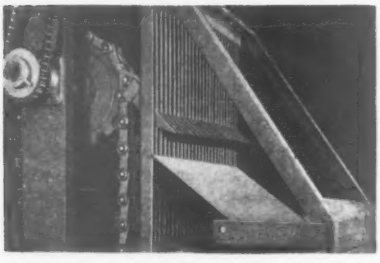
UNIT BAR SCREEN

Exclusive Pivoted Rake Design Assures Positive Raking from Absolute Bottom of Channel





Horizontal position of rake teeth at the beginning of cleaning cycle accomplishes raking from absolute bottom of channel. Gets under and picks up all screenings—does not push them away • Note unobstructed channel approach.



Rake making 45° radial drop to discharge screenings into trough—Note shear pin hub with tool steel shaft and hub inserts for perfect shear action.

THE "AMERICAN" UNIT SCREEN

Completely automatic with a limit switch which stops operation with the rake out of the flow when time control or water level control cycles have been completed • Easily installed as a unit in concrete channels • Total height of unit from mounting floor to motor base is only five feet • The entire above-floor structure is enclosed with stainless steel panels secured by quick opening fasteners to permit easy inspection and access.

Send for Technical Supplement "MS"

See Working Model on Display in Booths 47-48 at Convention of the Federation of Sewage and Industrial Wastes Associations—Miami, Florida—Oct. 13-16, 1953

AMERICAN WELL WORKS

IN OUR 85TH YEAR
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Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH • ENGINEERING • MANUFACTURING

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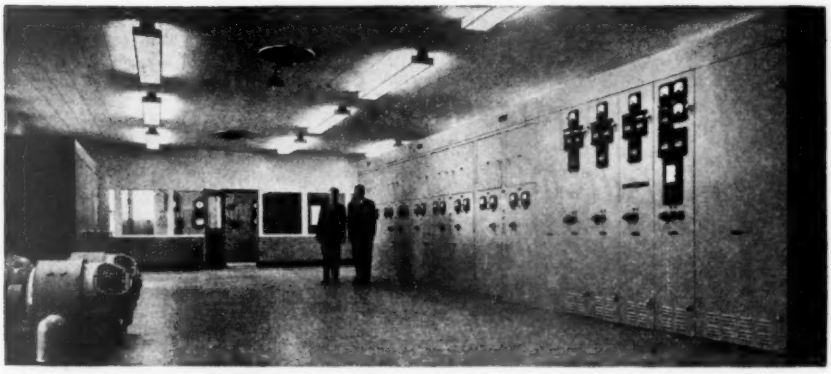
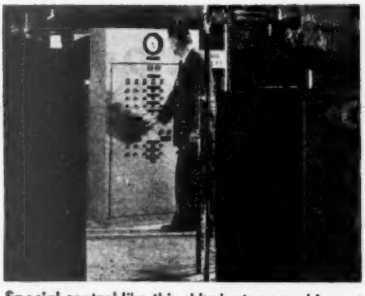


Typical of modern G-E equipment is this switchgear and Limitamp control lineup at a new west coast plant.

3-way aid for your Clean Waters plan



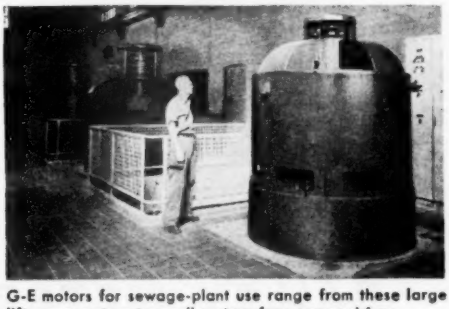
Special control like this chlorinator panel is part of complete G-E equipment for sewage plants.

Available now to all communities faced with the need for new or expanded sewage-treatment facilities is this three-way help from General Electric:

1. **Community-action program,** including the film *Clean Waters* to aid you in increasing public support for necessary new projects.
2. **Engineering assistance** to your consultants or engineers in electrical-system planning.
3. **Co-ordinated electrical equipment** supplied from the complete G-E line of motors, control and power distribution equipment.

To take advantage of this complete service, contact your nearest G-E Apparatus Sales Office early in the planning of your project. General Electric Co., Schenectady 5, N. Y. 666-75

Clean Waters program consists of film, manual *Modern Sewage Treatment*, handout leaflets.



G-E motors for sewage-plant use range from these large lift-pump motors to small motors for process drives.

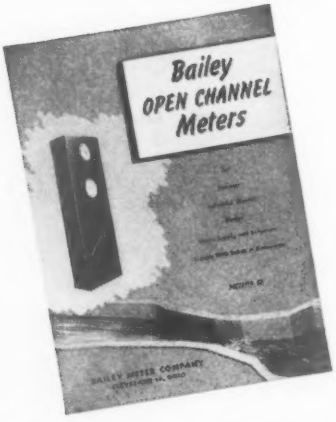
Engineered Electrical Systems for Sewage Plants

GENERAL ELECTRIC

For trouble-free, low cost measurement of—

SEWAGE
INDUSTRIAL WASTES
SLUDGE
IRRIGATION WATER

BAILEY
OPEN CHANNEL METERS
Offer These Advantages:



1. Easy to Install
2. Retain Accuracy
3. Self-Cleaning
4. Adjustable Capacities
5. Totalize Multiple Flows
6. Chemical Feed Control
7. Flow and Ratio Controls

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MU22

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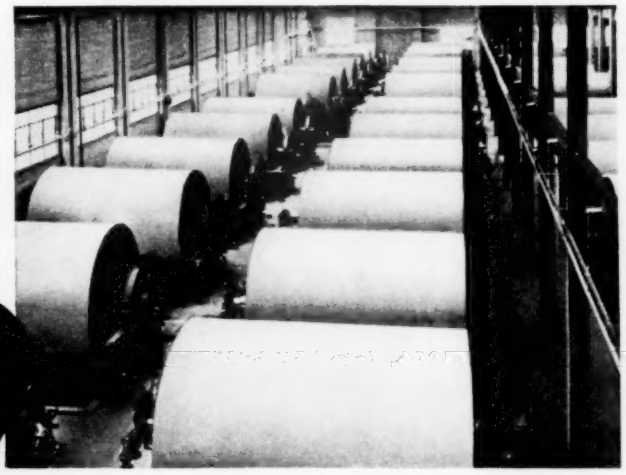
1066 IVANHOE ROAD • CLEVELAND 10, OHIO

METERS and CONTROLS for SEWAGE and WATER

VENTURI TUBES, FLUMES, WEIRS, NOZZLES, ORIFICES • DIRECT MECHANICAL AND REMOTELY LOCATED REGISTERS • AIR-OPERATED, ELECTRONIC AND ELECTRIC CONTROLS.

See General American for

CREATIVE FILTER ENGINEERING



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Protective coatings for filter components.

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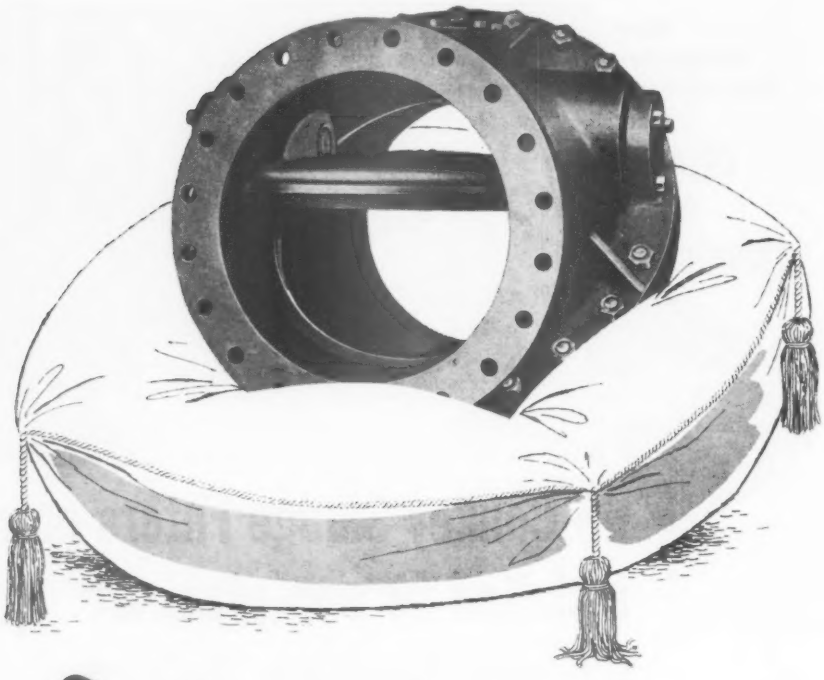

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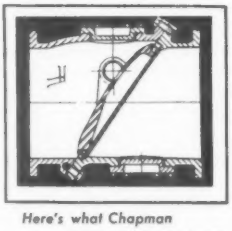

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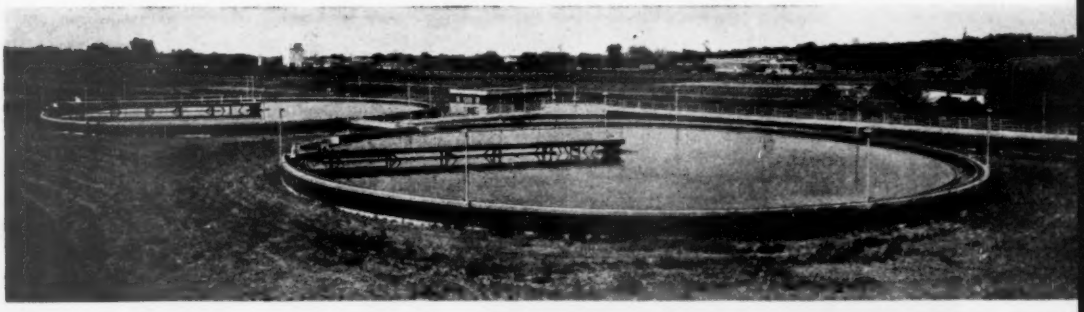

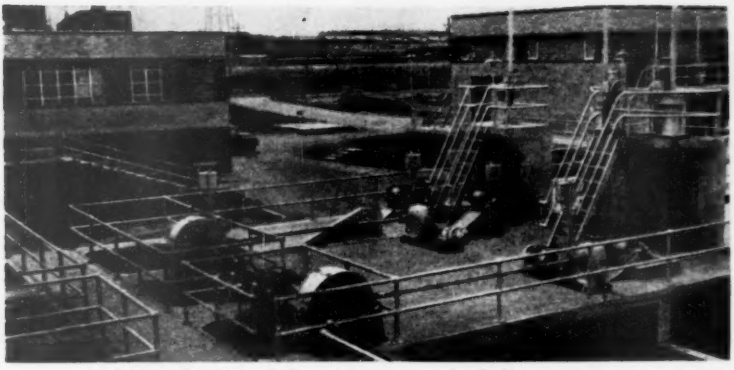

Link-Belt Circuline sludge collectors, mechanically-cleaned bar screens and Straightline grit collector help provide 114 mgd peak load capacity at Denver sewage treatment plant. Black & Veatch, Consulting Engineers.

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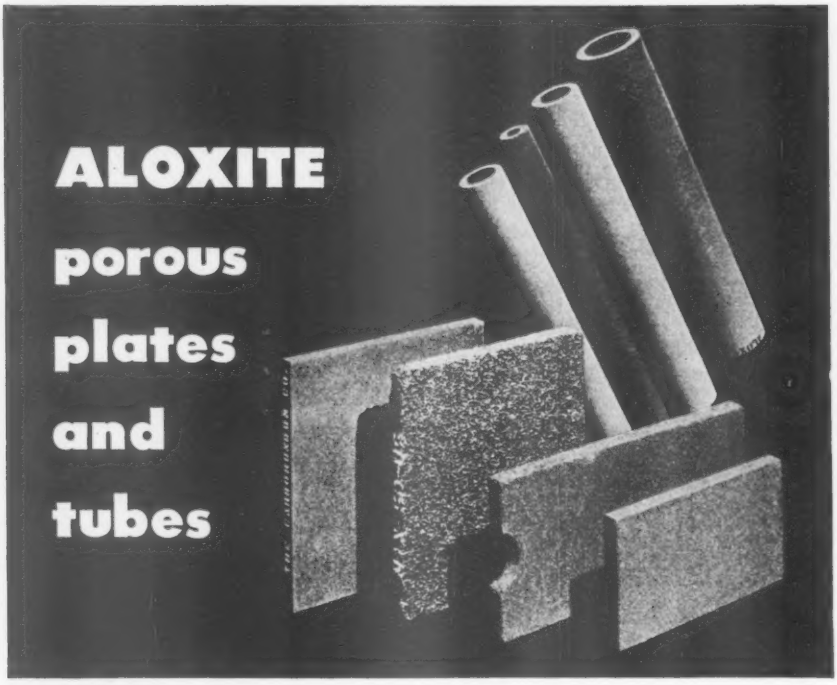

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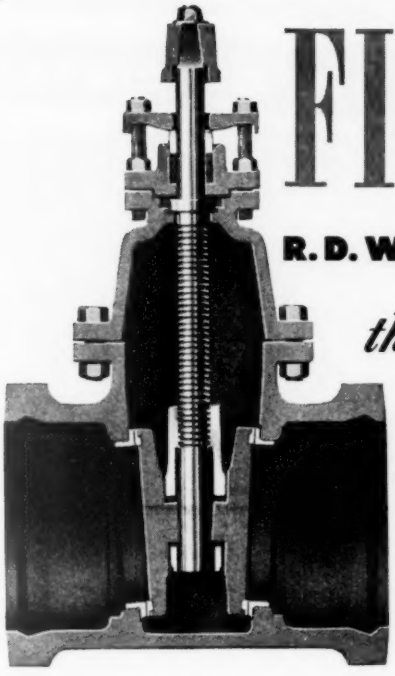

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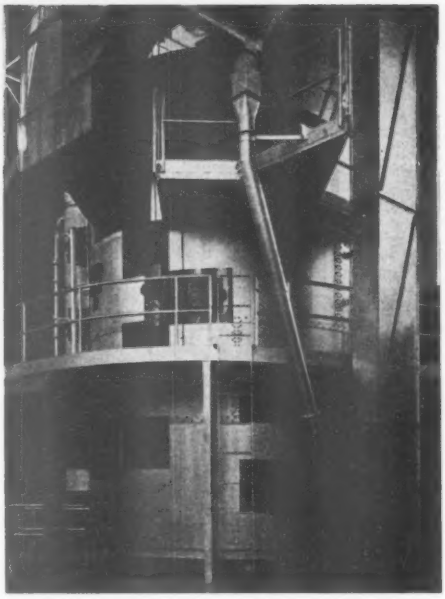

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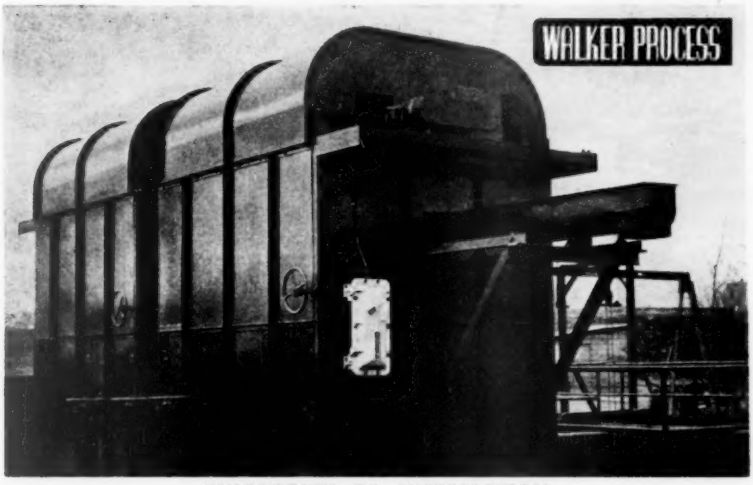

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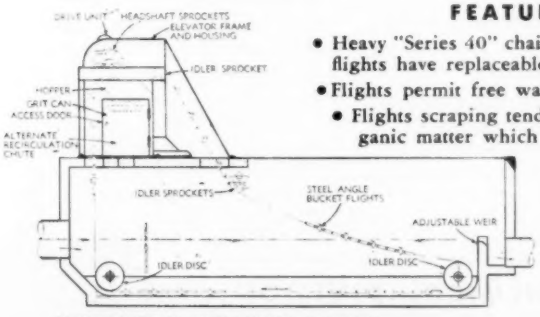

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- Heavy "Series 40" chain with steel bucket flights have replaceable wearing shoes.
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- Flights scraping tend to free settled organic matter which is in turn washed out of tank.
- Grit recirculation (adjustable) gives absolute control over putrescible content.

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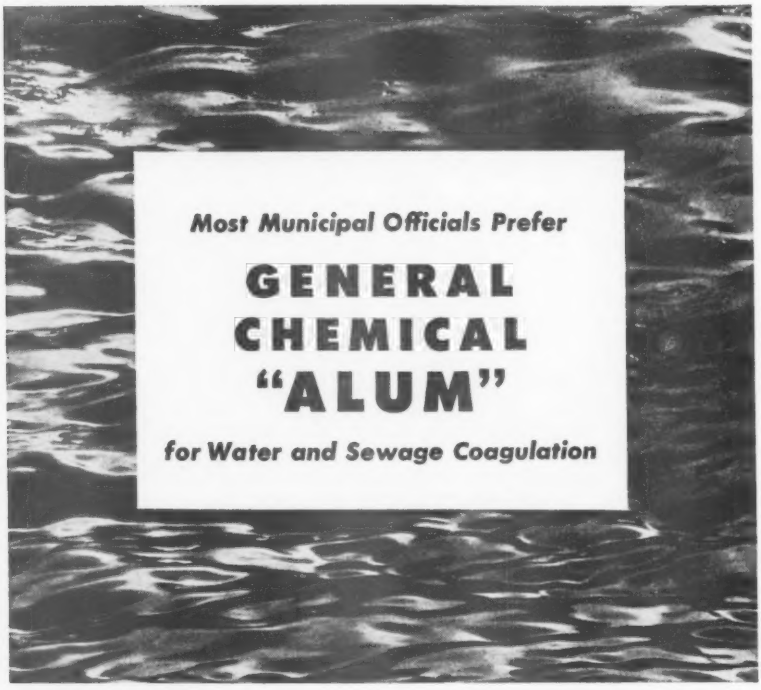

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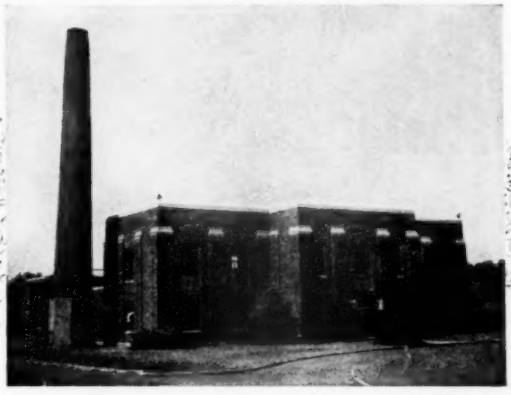

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Twelve years ago, the Sewage Treatment Plant at Springfield, Mass., was placed in operation. The sludge disposal equipment was a C-E Raymond Flash Dryer Unit capable of handling over 3 tons of dry solids per 8-hour day.

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In a typical year, the C-E Raymond Unit at Springfield flash dries and incinerates approximately 780 tons of dry solids. Incoming sewage contains approximately 213 parts per million of suspended solids. Removal, including grit, is about 61%.

The compact, flexible unit at Springfield, with its twelve years of successful service, highlights how effectively sewage sludge can be disposed of. This is true whether your community is small or large. To see how your locality, too, can be served with C-E Raymond Equipment, get in touch with the office nearest you. Addresses are listed below.

B-685A

INDUSTRIAL SLUDGES, TOO, are readily processed in C-E Raymond Equipment. Write for details.

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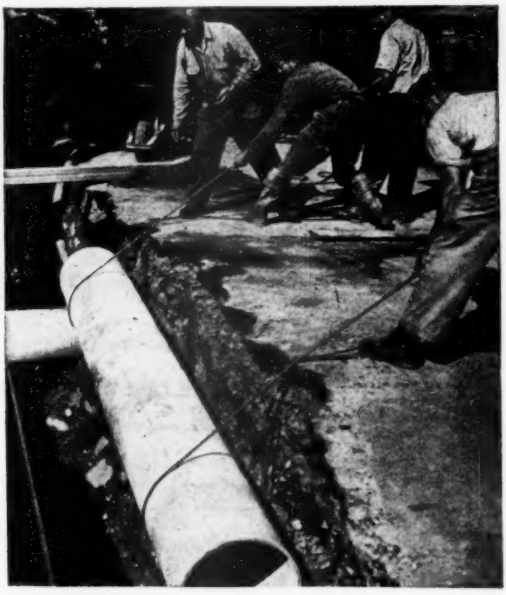
pipe faster...

speed completion

of entire job...



—Because of this RING-TITE JOINT used with Transite Sewer Pipe

Long 13-foot lengths of Transite* Pipe are rapidly assembled with the Ring-Tite Coupling. With it, dollars-and-cents savings will be realized every step of the way during construction of the line.

The 13-foot lengths reduce the number of joints and permit the pipe to be brought quickly and accurately to grade. Still more time is saved since each Ring-Tite joint can be checked as fast as it is assembled to reduce delays in backfilling, and speed completion of the job.

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Other money-saving advantages of Transite Sewer Pipe are found in its light weight and easy handling which reduce trucking costs and pay off in simplified operation. And, too, the Ring-Tite joint eliminates the necessity for hot compounds and the time-consuming procedures that go with their use.

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AND BUILDING SEWER PIPE, TOO!

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*Reg. U. S. Pat. Off.

Johns-Manville TRANSITE SEWER PIPE

for best

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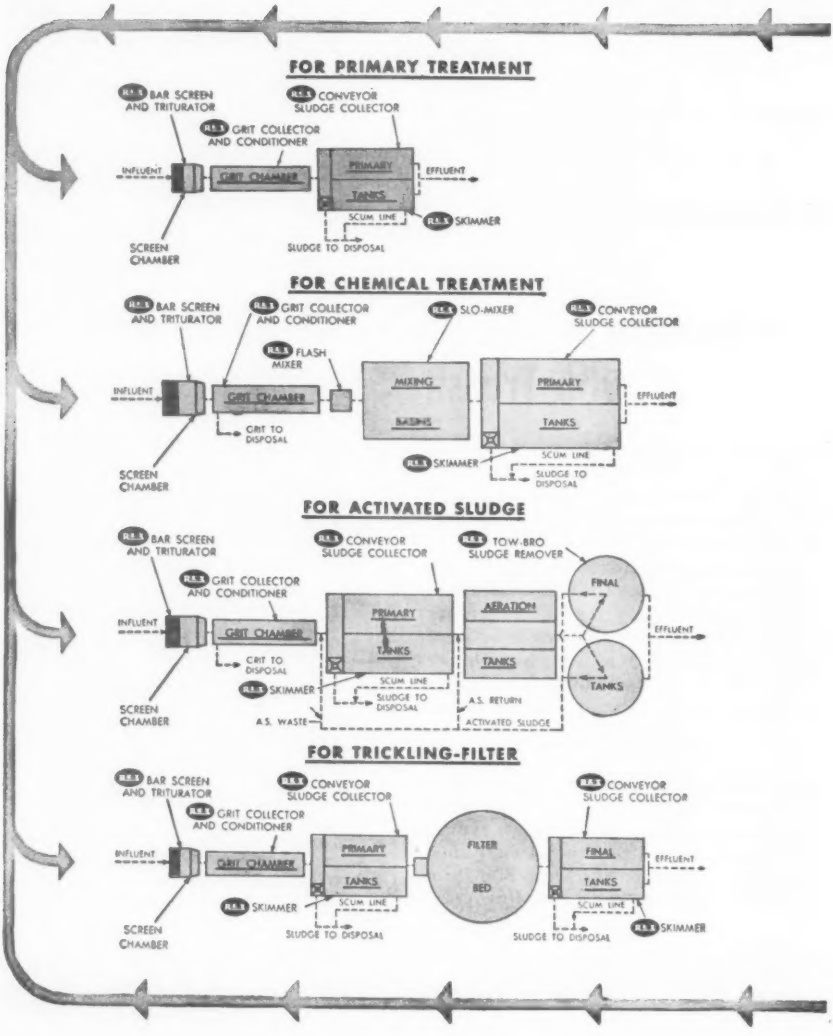

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Here's Why!

1. Modern treatment plants, regardless of size or type of process, require a multiplicity of arrangements and units.

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4. Rex Sanitation Engineers are well qualified by years of training and experience to help you select the equipment which will best fit into your plans. Call them in when your job is still in the planning stage. You'll find it pays off in greater plant efficiency, improved performance, lower operating and maintenance costs. Chain Belt Co., 4606 W. Greenfield Ave., Milwaukee 1, Wis.

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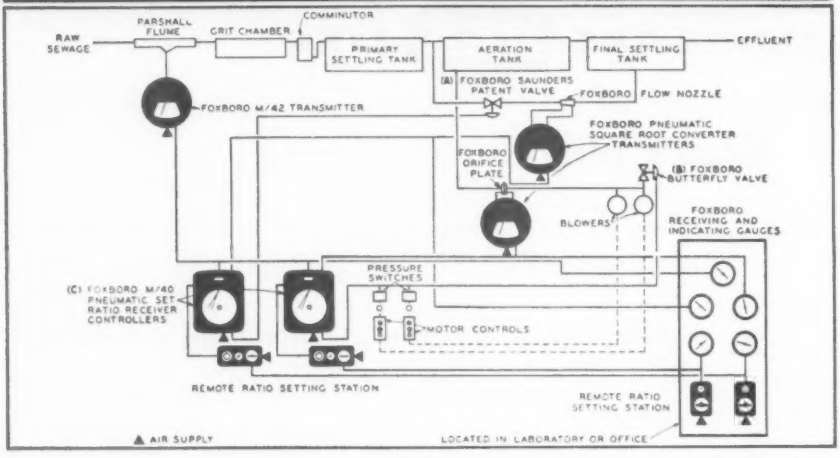
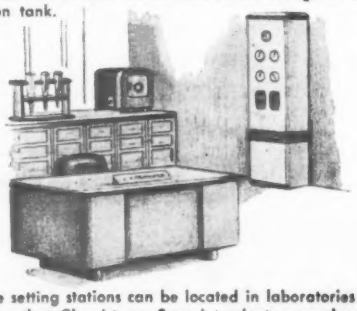
How to reduce "Bulking" in your activated sludge process



Schematic diagram shows typical installation. Rate of return sludge is controlled by (A) Foxboro Pneumatically Operated Valve located downstream from a Foxboro Flow Nozzle. Air flow rate is controlled by (B) Foxboro Butterfly Valve on blower relief line with an orifice plate in discharge line. Both control valves are actuated by (C) Foxboro M/40 Receiver Controllers and provide a fixed ratio of influent to air and return sludge in the aeration tank.

THIS FOXBORO system of aeration and return sludge control *automatically* maintains desired ratios of influent to air and to return sludge. You just set the selector switches at the proper ratios and Foxboro Controllers take over . . . no manual operation of valves . . . no need for 24-hour operational watches . . . less danger of "bulking" in final settling tank, regardless of variations in influent rate. Moreover, the Foxboro M/40 Ratio Receiver Controllers give you a permanent, continuous operational record for your files.

Why not learn more about this modern Foxboro Control System . . . write for Application Engineering Data Sheet 833-9. **The Foxboro Company, 889 Neponset Ave., Foxboro, Mass., U.S.A.**



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ACTIVATED SLUDGE CONTROL

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 25 **September, 1953** **Number 9**

Contents

Sewage Works

Bacteriological Studies of Sludge Digestion. I. A Facultative Anaerobe Isolated from Digested Sludge. By T. C. Buck, Jr., C. E. Keefer, and Hester Hatch 993

Application of Oxidation-Reduction Potentials to the Control of Sewage Treatment Processes. By Frederick E. Nussberger 1003

The Portland Sewage Treatment Plant. By John W. Cunningham 1015

Protozoa As Indicators in Activated Sludge Treatment. By S. Baines, H. A. Hawkes, C. H. Hewitt, and S. H. Jenkins 1023

Industrial Wastes

Disposal of Food Processing Wastes. By N. H. Sanborn 1034

Surface and Underground Disposal of Chemical Wastes at Victoria, Texas. By H. O. Henkel 1044

Water Conservation—A By-Product of Industrial Waste Control. By John L. Partin 1050

Oxidation of Cotton Kier Wastes. By Nelson L. Nemerow 1060

Stream Pollution

Computation of Pollution in a Vertically Mixed Estuary. By Henry Stommel 1065

Pollution Study of the Red Clay Creek Drainage Basin. II. Determination of Existing Stream Conditions. By A. Joel Kaplovsky and Jay L. Harmic ... 1072

Research Survey

Survey of Research Facilities and Projects—1953. By H. Heukelekian and W. H. Wisely 1077

The Operator's Corner

Outfall Sewer Repair at Little Rock. By T. W. Clapham 1092

Custom-Built Truck for Sewer Maintenance Work. By Alvin A. Appel 1100

The Daily Log, Kenosha, Wis. By Frank I. Vilen 1101

Trickling Filter Roach Invasion. By George T. Lohmeyer 1104

Interesting Extracts from Operation Reports: Muskegon, Mich.; Cleveland, Ohio (Easterly, Westerly, and Southerly) 1107

Joint Materials for Sewer Repairs. By A. P. Collins 1115

Tips and Quips 1117

Federation Affairs

Twenty-Sixth Annual Meeting Preview 1120

Reviews and Abstracts 1126

Proceedings of Member Associations

North Carolina Sewage and Industrial Waste Association 362a

Central States Sewage and Industrial Wastes Associations 364a

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Sewage Works

BACTERIOLOGICAL STUDIES OF SLUDGE DIGESTION

I. A Facultative Anaerobe Isolated from Digested Sludge

By T. C. Buck, Jr., C. E. Keefer, and Hester Hatch

Respectively, Assistant Director, Bureau of Laboratories, Baltimore City Health Department, and Deputy Sewerage Engineer and Senior Bacteriologist, Bureau of Sewers, Baltimore, Md.

Until comparatively recent times sewage sludge was digested by the crude and inefficient method of allowing it to remain for considerable periods of time in open tanks. Controlling the pH, adding suitable quantities of seeding material, and maintaining the sludge at the proper temperature were marked advances towards the scientific solution of the problem. Although these advances have been of great importance, it is believed that sludge digestion can be further accelerated as the result of scientific research. Just as specific organisms and their enzymes are responsible for the alcoholic fermentation of sugar or the preparation of dairy products, undoubtedly specific bacteria digest and stabilize the organic matter in sewage sludge. The authors envision the future possibility of seeding raw sludge with specific organisms that will rapidly and efficiently decompose the material in a minimum of time. With this thought in mind, studies were instituted to isolate a number of bacteria found in sewage sludge and to determine the role they play in sludge digestion. This paper, the first of a series, describes one of these bacteria, the procedure followed in isolating it, the medium formulated for it to grow on, and its biochemical reactions.

Anaerobic Decomposition Processes

During the past 100 years many investigators have studied anaerobic decomposition processes and have reported their findings in a number of scientific publications. This work has comprised studying and identifying the various organisms responsible for the anaerobic decomposition of organic matter, determining the environmental conditions under which these organisms live, investigating the various materials that are decomposed together with their products of decomposition, and studying other allied problems. In 1930 Buswell and Neave (1), and again in 1939 Buswell and Hatfield (2), prepared excellent historical reviews of the subject, giving 220 references in the earlier publication and 394 in the latter. Much of the work has been broad in scope and has not been limited to the anaerobic decomposition of any one class of materials.

From time to time investigators have reported the isolation and identification of anaerobic fermenting bacteria, only to have their claims questioned by subsequent workers. For example, Omelianski (3)(4)(5)(6)(7), in his studies of the decomposition of cellulose, reported the isolation of two anaerobes, *Bacillus methanizenes* and *Bacillus fossicularum*. The purity of these cultures was later questioned by McBeth and Scales (8) and Clausen (9). In 1933 Stephenson and Stickland (10), in studying methane fermentation, stated that they had isolated an organism in pure culture from river mud. In a recent publication Stadtman and

Barker (11) question the validity of this conclusion. As of 1939 Heukelekian and Heinemann (12) state that methane-producing organisms "have never been isolated in pure culture."

Since 1936 Barker (11)(13)(14)(15)(16)(17)(18)(19)(20)(21)(22) and his associates have prepared a series of articles dealing with methane fermentation and have studied several organisms capable of producing methane. His work has included an investigation of the compounds attacked by methane-producing organisms and their products of decomposition.

Only a few organisms that produce methane seem to have been isolated in pure culture. As the complete cultural characteristics of none of these are given in "Bergey's Manual" (23), their proper classification is open to question.

Bacteriological Studies of Sludge Digestion

Although many investigations have been made to determine the different factors that affect sludge digestion, little has been published describing the various bacteria or groups of bacteria responsible for sludge digestion.

In 1922–25 Hotchkiss (24)(25)(26)(27)(28) conducted a series of bacteriological studies of the sludge in an Imhoff tank at the Plainfield, N. J., sewage treatment works. The bacteria were classified into 10 groups in accordance with the substances digested or produced. An inverse relationship between the numbers of albumen digesters and hydrogen sulfide producers was observed.

Rudolfs *et al.* (29) reported on the number of albumen digesters, hydrogen sulfide producers, nitrate reducers, and lactose fermenters in a covered sludge digestion tank. Desirable digestion was maintained by keeping a uniform and not excessively high level of bacteria.

Gaub (30) investigated the different groups of bacteria in the sludge drawn from the Imhoff tanks at the Plainfield sewage treatment works. Of the bacteria studied, 100 per cent were ammonifiers under aerobic and anaerobic conditions. Non-proteolytic bacteria, as determined by their reaction to milk, were more abundant than proteolytic forms.

Heukelekian and Rudolfs (31) investigated the numbers of different physiological groups of bacteria in digesting sewage sludge kept at temperatures varying from 10° to 35° C. They found a wide divergence between the total numbers of lactose fermenters and spore-forming lactose fermenters. At the higher temperatures the latter organisms constituted the majority of the lactose fermenting organisms and the total number of organisms was greatly reduced.

Heukelekian and Heinemann (12)(32)(33)(34) studied those organisms found in sewage sludge capable of fermenting acetic and butyric acids and ethyl alcohol with the production of methane. As the organisms they used were not in pure culture, there is no assurance that the methane was produced without the aid of the associated bacteria.

Buswell (35) has prepared a brief review of the microbiology of anaerobic sludge digestion and has given the results of his observations in digesting the solids produced at two industrial plants. By using radioactive carbon in the form of barium carbonate, Buswell and Sollo (36) concluded that in the fermentation of acetic acid methane is derived from the acid and not from carbon dioxide.

Liebmann (37) reported on the role of methane-producing bacteria in the digestion of sewage sludge and fresh horse manure containing varying quantities of water.

Isolation and Study of *Streptococcus diploidus*

This paper describes the procedure followed in isolating and growing in

pure culture one of the liquefying organisms found in digested sewage sludge. The organism is a Gram-positive, non-spore forming coccus, which grows in clumps and chains and is a facultative anaerobe. The organism was isolated from actively digesting sewage sludge collected from the Back River sewage treatment works serving Baltimore, Md. The temperature of the sludge during digestion was 35° C. A comprehensive study of this organism was made, together with an investigation of its biochemical, morphological, and physiological characteristics.

One of the prime difficulties of isolating the organism in pure culture was the interference of several strains of actively motile, slime-wall-producing organisms, which probably belonged to the *Proteus* group. Although these organisms may be of some significance in the digestion of sludge, their elimination rather than their identification was desired. The repeated failure to obtain well-isolated colonies was also due to the inadequate number of organisms that were to be isolated when observed on wet mounts, intravital staining mounts and Gram-stained smears.

Numerous procedures were adopted to get the organism in pure culture. The use of inhibitory dyes proved to be inadequate. Various antibiotics were tried, but discarded. Heat reduction was of no value, as the organism was heat labile.

In isolating the organism in pure culture, the use of the dilution-plate method together with various chemicals, including several phenols, was quite important for the following reasons:

1. An examination with a Greenough (30×) microscope revealed whether or not a slime-wall motile organism was in close proximity to well-defined colonies.

2. Fishing out this colony under the same magnification presented no difficulty.

3. The addition of reducing compounds was important. These were used in many instances at one-fourth to one-third of their usual recommended strength.

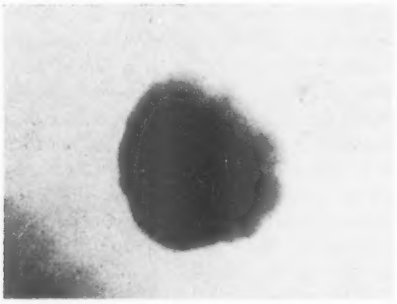
One of the essentials for the successful isolation of the organism was the use of modified trypticase soy agar as a substrate, which was adjusted to a pH of 7.6 or higher. The procedure of replating the organism, transferring it to shake tubes and replating it again was repeated at least four to six times to assure that the organism was in pure culture.

Morphology

After obtaining well-isolated colonies on Phytone medium, those near the surface were different from those some distance below the surface. Two types of colonies, having M–S–R forms, were observed (Figure 1). One was entire and elliptical, approximately 2 by 5 mm. The other was lobate and circular, with a diameter of about 3 to 4 mm. The latter colony contained a small dark elliptical center, a number of small brown daughter colonies, and a dark-colored concentric ring. Transferring each type of colony to broth and then replating produced both types of colonies. This procedure was repeated at least 10 times with no variation in the characteristics of the colonies. The methylene-blue oxygen indicator gave colonies of a distinct blue color in agar plates 48 hr. or older, where the indicator had diffused several millimeters below the surface. However, deeper colonies were distinctly yellow.

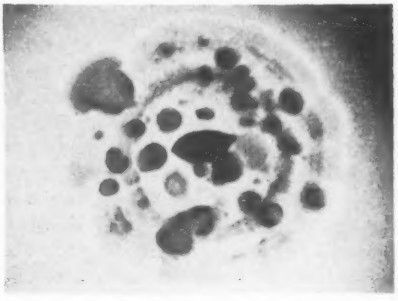
Transfers to shake tubes and broth when stained by Burke's Gram method revealed Gram-positive and Gram-negative cocci in small clumps and chains ranging across the entire microscopic field when using an oil-emersion objective. The young cultures grown in broth less than 24 hr. old were all Gram-positive. Broth cultures, 4 days

(a) Primary colony.



(b) Secondary colony.

(c) Secondary colony forming daughter colonies.



(d) Typical colony with daughter colonies.

FIGURE 1.—Colony formation of *Streptococcus diploidus*.

or older, contained many Gram-negative pleomorphic cocci in clumps and chains. Some of the pleomorphic forms were at least five times larger than the smaller cells (Figure 2).

Smears made from semi-solid and solid shake tubes varied in the sizes of the clumps of bacteria, and the Gram-positive chain formations were fewer and shorter. Young cultures incubated in these media for less than 24 hr. revealed no Gram-negative organisms.

The size of the organism varied from 1.2 to 1.8 microns in diameter. The organism from older cultures was highly refractile when observed by diminishing light through an Abbe condenser.

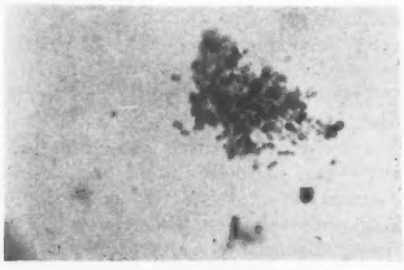


FIGURE 2.—Gram stain of *Streptococcus diploidus*.

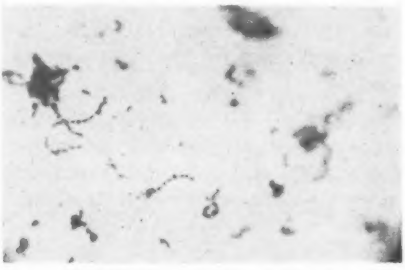


FIGURE 3.—Wet mount of *Streptococcus diploidus*.

Capsules were observed when Hiss stain (38) was used. Moreover, a very slight halo was noted when the organism was treated with Mallory stain. No metachromatic granules were observed by direct staining with Loeffler's methylene blue, aqueous gentian violet, or a methylene-blue-iodine combination after proper fixing with heat and thorough washing with tap and distilled water.

No motility was noted in the semisolid media as indicated by growth deviation from the line of inoculation. The variation in size as observed on many wet mounts was from 0.2 to 0.3 micron. Somewhat larger diploidal organisms in long chains, which were obtained from broth cultures, were observed in methylene-blue wet mounts (Figure 3) than with the other stains. No spore-like structures were seen in any of the innumerable microscopic examinations. From time to time cocci were so close together that they were thought at first to be bacilli until higher magnification revealed definite cleavages. Yeast-like elliptical structures were frequently observed in old cultures.

Growth Phase

The organism grew well at 20°, 25°, 35°, and 45° C. in various media. Optimum growth occurred at 35° C. within 4.5 hr.

Effect of pH of Media

Several different media were employed to determine the range in pH over which growth occurred. After several trials at the optimum temperature, growth took place from a pH of 5.5 to 8.5, with the optimum at 7.6. The organism grew very rapidly at a pH of 7.6 with growth in 5 hr.

Thermal Death Time

To establish the thermal death time a constant-temperature water bath maintained at 67.5° ± 0.2° C. was employed. Thirty-eight tubes of broth were inoculated and incubated at 35° C. for approximately 18 hr. Good growth was observed in all tubes; these were compared with McFarland's (39) nephelometer scale. Readings were between No. 5 and 6, which indicated about 1,600,000,000 organisms per ml. Every 5 min. for 175 min. 0.1 ml. was extracted according to Chick's method (40). No growth was obtained when reinoculated and incubated for 24 and 48 hr. after having been exposed for 15 min. to a temperature of 67.5° C. All autoclaved controls maintained at a temperature of 35° C. for 3 days were sterile. A preheating time of 15 min. was used with a control culture in an open tube, into which a certified thermometer was immersed. All tubes were agitated every 5 min. throughout the observation period. The thermal death time of this organism at 67° C. was 15 min.

Pathogenicity

Mice and guinea pigs were inoculated intramuscularly and intraperitoneally with 0.5-ml. portions of a 24-hr., heart-infusion broth culture. Control animals were inoculated with sterile broth. Animals were also inoculated with washed organisms; that is, the organisms were grown in broth for 24 hr. at 35° C., centrifuged, resuspended in the same quantity of 0.85 per cent physiological salt solution, again washed, and inoculated into the two kinds of animals. All animals, observed daily for 21 days and then once a week for 3 months, were normal as far as could be ascertained. The animals inoculated with the organism were autopsied; all findings at the site of the inoculations were negative. Cultural recovery of the organisms from the site of injection was also negative. It is concluded that this organism when inoculated into these animals was not pathogenic.

Cellulose Digestion

The organism was inoculated into 12 tubes provided with screw caps, which

contained broth together with various forms of cellulose such as cotton string, Whatman filter paper No. 1 (a grade of heavy filter paper), and Scotch tape with the adhesive removed. Three of the tubes were then incubated for 87 days at 35° C. Good growth was obtained in all tubes. No decomposition of cellulose was observed when the various materials were transferred to a Petri dish and examined by a Greenough microscope (30×). It was concluded, therefore, that this organism was not a cellulose digester.

Alcohol Tolerance

Broth cultures were inoculated into 10 tubes containing 0 to 10 per cent of 95 per cent ethyl alcohol. Good growth was obtained in an 8 per cent concentration of alcohol, but growth was not observed in 9 and 10 per cent concentrations. The results were the same when using 99 per cent methyl alcohol. This organism failed to produce gas from either of the alcohols.

Utilization of Fatty Compounds

One gram each of the following fatty compounds was autoclaved, tested for sterility, and placed in vials containing a good growth of the organism:

1. Olive oil
2. Butter
3. Stearate
4. Cottonseed oil
5. Soy bean oil
6. Paraffin oil
7. Linseed oil

The materials were incubated at 35° C. for 20 days and shaken twice a day except on holidays. No disintegration or utilization of the fatty materials was observed.

Bile Solubility Test

Bile solubility tests were performed with a 0.5 per cent aqueous solution of Bacto ox bile. Five milliliters of a 24-hr. broth culture were added to equal parts of the solution. No lysis occurred at the end of 1 hr. when incubated at 35° C. The organism, therefore, was not bile soluble.

Digestion of Sewage Sludge

Streptococcus diploidus was inoculated into a number of 10-, 30-, and 300-ml. portions of raw sewage sludge and incubated at 35° C. Gas was produced within about 1.5 hr. This rapid production of gas was quite unexpected, as the growth phase of the organism had been found to be about 4.5 hr. To date there is no indication that the organism *per se* produces gas. The inference is that the organism during this early stage of sludge decomposition produces enzymes that liquefy and digest certain organic compounds that are fermented in turn by other organisms. As the results of these small-scale experiments were quite promising, experiments, which will be described in a subsequent paper, were conducted on a considerably larger scale.

Biochemical Reactions

The *Streptococcus diploidus* organism was subjected to 40 biochemical tests, which were made in triplicate. The reactions (Table I) observed at the end of 1, 2, 6, 10, and 20 days revealed the following interesting facts:

1. Acid was formed without the production of gas in seven of the carbohydrates tested.
2. Slow acidification of litmus milk occurred with the reduction of the dye to its leuco base in the lower third of the tube. Coagulation was observed on the seventh day again in the lower third of the tube, and on the fourteenth day no liquefaction was evident. At the end of 20 days no liquefaction was obtained.
3. Modified Loeffler's medium (41) inoculated with the organism failed to liquefy within 20 days. This reaction indicated that the organism did not have the power to break down and liquefy ox serum and egg albuminoids.

TABLE I.—Biochemical Reactions of *Streptococcus Diploidus*

Medium	1 Day			2 Days			6 Days			10 Days			20 Days		
	Growth	Acid	Gas	Growth	Acid	Gas	Growth	Acid	Gas	Growth	Acid	Gas	Growth	Acid	Gas
Adonitol	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.
Arabinose	±	Alk.	—	+	Alk.	Neg.	+	Alk.	Neg.	+	Alk.	Neg.	+	Alk.	Neg.
Bile solubility	Neg.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Blood-agar	±[1]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Brilliant-green lactose broth	Neg.	—	—	±	—	—	±	—	—	±	—	—	±	—	—
Catalse test	—	—	—	Neg.	—	—	—	—	—	—	—	—	Neg.	—	—
Choc. agar slant	±	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chopped meat	++++	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Citrate	Neg.	Neg.	Neg.	±	Neg.	Neg.	±	Neg.	Neg.	±	Neg.	Neg.	±	Neg.	Neg.
Dextrose	+++	Ac.	Neg.	+++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.
Dulcitol	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.
Erythritol	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.
Galactose	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gelatine	Neg.	—	—	—[2]	—	—	—[2]	—	—	—[2]	—	—	—[2]	—	—
Glyserol	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.
Heart inf.	++++	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hydro. sul.	—	Ac.	Neg.	—	—	—	—	—	—	—	—	—	—	—	—
Indol	Neg.	—	—	Neg.	—	—	Neg.	—	—	Neg.	—	—	Neg.	—	—
Inositol	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.
Inulin	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.
Lactose	+	Alk.	Neg.	+++	Ac.	Neg.	+++	Ac.	Neg.	+++	Ac.	Neg.	+++	Ac.	Neg.
Levulose	+++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.
Litmus milk	Neg.	—	—	—[3]	—	—	—[4]	—	—	—[5]	—	—	—[6]	—	—
Loefflers	±[2]	—	—	—[3]	—	—	—[2]	—	—	—[3]	—	—	—[3]	—	—
Malonate	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Maltose	+++	Ac.	Neg.	+++	Ac.	Neg.	+++	Ac.	Neg.	+++	Ac.	Neg.	+++	Ac.	Neg.
Mannitol	±	Neg.	Neg.	+	Alk.	Neg.	+	Alk.	Neg.	+	Alk.	Neg.	+	Alk.	Neg.
Methyl red	Neg.	—	—	Neg.	—	—	Neg.	—	—	Neg.	—	—	Neg.	—	—
Raffinose	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.
Rhamnose	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.
Saccharose	±	Alk.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.
Salcin	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.
Sorbitol	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.	±	Alk.	Neg.
Stand. agar broth	±	—	—	±	—	—	±	—	—	±	—	—	±	—	—
Stand. agar slant	±	—	—	±	—	—	±	—	—	±	—	—	±	—	—
Tartrate	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Trypticase soy slant	++	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Urease	±	—	—	—	—	—	—	—	—	—	Yellow	—	±	—	—
Voges-Pros.	Neg.	—	—	Neg.	—	—	—	—	—	—	—	—	Neg.	—	—
Xylose	+	Alk.	Neg.	+	Alk.	Neg.	+	Alk.	Neg.	+	Alk.	Neg.	+	Alk.	Neg.

[1] No hemolysis, no discoloration. [2] No liquefaction in 20 days. [3] Reduced to leuco-base. [4] Acid, partially coagulated. [5] Acid, coagulated. [6] Slightly acid.

4. Blood-agar slants and plates gave very slight growth (veil-like, erose) without the production of methemoglobin or hemolysis. Control tubes containing inoculations on blood-agar held at refrigeration temperature (6° C.) when compared with the inoculated tubes and plates incubated at 35° C. showed no change.

5. Catalase tests gave negative results at the end of 2 and 20 days. The substrate controls were also tested and were negative.

6. Gelatin inoculated and incubated at 20° and 35° C. gave a fair amount of growth along the line of inoculation at 20° C. and a heavier stratiform growth at 35° C. No liquefaction was observed after 20 days of incubation.

7. The IMVIC tests were performed according to "Standard Methods" (42). No growth was obtained in any of the tubes.

8. Triple-sugar-iron medium heavily inoculated in the butt, and also on the slant, gave good growth, but without the production of hydrogen sulfide or gas.

9. Urease gave only a ± growth after 1, 2, and 6 days; no ammonia was produced.

10. Salcin produced the most prolific growth in the shortest time at 35° C. of any of the carbohydrates listed in Table I.

11. When using Koser's (43) citrate broth, less than a ± growth occurred in 48 hr. and there was no change thereafter for 20 days. This reaction was of interest, because the medium supplied the sole source of carbon, which could be only partially utilized.

12. Although a number of attempts were made to find a medium that the organism would ferment, none was found from which gas was produced. However, the organism was capable of producing gas when it was inoculated into raw sewage sludge. On the other hand, no gas was produced, as will be described in a subsequent paper, if the sludge was first autoclaved.

Conclusions

1. A liquefying, facultative anaerobic, non-pathogenic, Gram-positive, non-spore forming coccus that grows in clumps and chains was isolated from digesting sewage sludge. The organism grows at temperatures from 20° to 45° C., with optimum growth at 35° C., and at pH values from 5.5 to 8.5, with optimum growth at 7.6.

2. No reference has been found in the literature indicating that this organism has been previously isolated.

3. The morphological, biochemical, and cultural reactions of this organism indicate that it belongs to the *Streptococcus* genus. *Streptococcus diploidus* is suggested as the name for the organism.

Acknowledgments

The investigation described in this paper is part of a general program involving the study of the biological factors responsible for the digestion of sludge at the Back River sewage treatment works, which is under the general supervision of P. L. Holland, director, Department of Public Works, Baltimore, Md., and John J. Hunt, sewerage engineer. Abel Wolman is consultant to the Department of Public Works.

Material assistance in conducting these experiments was rendered by the Baltimore City Health Department, of which Dr. H. Williams is commissioner, and Clinton L. Ewing is director of the Bureau of Laboratories.

Helpful suggestions were also offered by Dr. J. Howard Brown, associate professor of bacteriology, Emeritus, School of Medicine, Johns Hopkins University.

R. J. Trautman, principal associate engineer, has direct supervision of the sewage works, and Paul L. Smith is plant superintendent.

References

1. Buswell, A. M., and Neave, S. L., "Laboratory Studies of Sludge Digestion." Bull. No. 30, Illinois State Water Survey (1930).
2. Buswell, A. M., and Hatfield, W. D., "Anaerobic Fermentations." Bull. No. 32, Illinois State Water Survey (1939).
3. Omeliansky, M. V., "Sur le fermentation de la cellulose." *Arch. Scien. Biol.*, **7**, 411 (1899).
4. Omelianski, W., "Über die Gärung der Cellulose." *Centralbl. f. Bakt.*, II, **8**, 193, 225, 257, 289, 321, 353, 385 (1902).
5. Omelianski, W., "Über die Trennung der Wasserstoff- und Methangärung der Cellulose." *Centralbl. f. Bakt.*, II, **11**, 369 (1904).
6. Omelianski, W., "Die histologischen und chemischen Veränderungen der Leinstengel unter Einwirkung der Mikroben der Pektin- und Cellulosegärung." *Centralbl. f. Bakt.*, II, 33 (1904).
7. Omelianski, W., "Über Methan—Bildung in der Natur bei biologischen Prozessen." *Centralbl. f. Bakt.*, II, **15**, 673 (1906).
8. McBeth, I. G., and Scales, F. M., "The Destruction of Cellulose by Bacteria and Filamentous Fungi." Bull. No. 266, U. S. Dept. of Agr., Bur. Plant Indus. (1913).
9. Clausen, P., "Studien über anaerobe Zellulosebazillen unter besonderer Berucksichtigung der Züchtungstechnik." *Centralbl. f. Bakt.*, II, **84**, 20 (1931).
10. Stephenson, M., and Stickland, L. H., "Hydrogenase. III. The Bacterial Formation of Methane by the Reduction of One-Carbon Compounds by Molecular Hydrogen." *Biochemical Jour.*, **27**, 1517 (1933).
11. Stadtman, T. C., and Barker, H. A., "Studies on the Methane Fermentation. X. A New Formate-Decomposing Bacterium, *Methanococcus vannielii*." *Jour. Bact.*, **62**, 269 (1951).
12. Heukelekian, H., and Heinemann, B., "Studies on the Methane-Producing Bacteria. I. Development of a Method for Enumeration." *Sewage Works Jour.*, **11**, 3, 426 (May, 1939).
13. Barker, H. A., "On the Biochemistry of the Methane Fermentation." *Arch. für Mikrobiol.*, **7**, 404 (1936).
14. Barker, H. A., "Studies Upon the Methane-Producing Bacteria." *Arch. für Mikrobiol.*, **7**, 420 (1936).
15. Barker, H. A., "The Production of Caproic and Butyric Acids by the Methane Fermentation of Ethyl Alcohol." *Arch. für Mikrobiol.*, **8**, 415 (1937).
16. Barker, H. A., "Studies Upon the Methane Fermentation. IV. The Isolation and Culture of *Methanobacterium omelianskii*." *Jour. Microbiol. Serol.*, **6**, 201 (1939–40).
17. Barker, H. A., Ruben, S., and Kamen, M. D., "The Reduction of Radioactive Carbon Dioxide by Methane-Producing Bacteria." *Proc. Nat. Acad. Sciences*, **26**, 426 (1940).
18. Barker, H. A., "Studies on the Methane Fermentation. V. Biochemical Activities of *Methanobacterium omelianskii*." *Jour. Biol. Chem.*, **137**, 153 (1941).
19. Barker, H. A., "Studies on the Methane Fermentation. VI. The Influence of Carbon Dioxide Concentration on the Rate of Carbon Dioxide Reduction by Molecular Hydrogen." *Proc. Nat. Acad. Sciences*, **29**, 184 (1943).
20. Stadtman, T. C., and Barker, H. A., "Studies on the Methane Fermentation. VII. Tracer Experiments on the Mechanism of Methane Formation." *Arch. Biochem.*, **21**, 256 (1949).
21. Stadtman, T. C., and Barker, H. A., "Studies on the Methane Fermentation. VIII. Tracer Experiments on Fatty Acid Oxidation by Methane Bacteria." *Jour. Bact.*, **61**, 67 (1951).
22. Stadtman, T. C., and Barker, H. A., "Studies on the Methane Fermentation. IX. The Origin of Methane in the Acetate and Methanol Fermentations by *Methanosarcina*." *Jour. Bact.*, **61**, 81 (1951).
23. Breed, R. S., Murray, E. G. D., and Hitchens, A. P., "Bergey's Manual of Determinative Bacteriology." 6th Ed. (1948).
24. Hotchkiss, M., "Bacteriological Studies on the Imhoff Tanks and Sprinkling Filter Bed." Bull. 390, N. J. Agric. Exper. Station (July, 1923).
25. Hotchkiss, M., "Bacteriological Investigations on Operating and Resting Imhoff Tanks." Bull. 403, N. J. Agric. Exper. Station (July, 1924).
26. Hotchkiss, M., "Studies on the Biology of Sewage Disposal. A Survey of the Bacteriological Flora of a Sewage Treatment Plant." *Jour. Bact.*, **7**, 437 (1924).
27. Hotchkiss, M., "Bacteriological Studies on Imhoff Tanks." Bull. 427, N. J. Agric. Exper. Station (Feb., 1926).
28. Hotchkiss, M., "Factors Influencing the

Bacterial Flora of an Imhoff Tank." *Jour. Amer. Pub. Health Assn.*, **15**, 702 (1925).

29. Rudolfs, W. Heukelekian, H., Zeller, P. J. A., Peterson, D., and Downes, J. R., "Effect of Lime on Sludge Digestion." Rep. of Sewage Substation, N. J. Agric. Exper. Station (June, 1926).
30. Gaub, W. H., Jr., "A Bacteriological Study of a Sewage Disposal Plant." Bull. 394, N. J. Agric. Exper. Station (Mar., 1924).
31. Heukelekian, H., and Rudolfs, W., "Effect of Temperature on Bacterial Numbers in Digesting Sewage Sludge." *Jour. Bact.*, **17**, 247 (1929).
32. Heukelekian, H., and Heinemann, B., "Studies on the Methane-Producing Bacteria. II. Enumeration in Digesting Sewage Solids." *Sewage Works Jour.*, **11**, 3, 426 (May, 1929).
33. Heukelekian, H., and Heinemann, B., "Studies on the Methane-Producing Bacteria. III. Digestion of Sewage Solids by the Addition of Enriched Cultures of Methane-Producing Organisms." *Sewage Works Jour.*, **11**, 4, 571 (July, 1939).
34. Heukelekian, H., and Heinemann, B., "Studies on the Methane-Producing Bacteria. IV. Growth of Methane-Producing Organisms in Supernatant Sludge Liquors." *Sewage Works Jour.*, **11**, 6, 965 (Nov., 1939).
35. Buswell, A. M., "Important Considerations in Sludge Digestion. II. Microbiology and Theory of Anaerobic Digestion." *Sewage Works Jour.*, **19**, 1, 28 (Jan., 1947).
36. Buswell, A. M., and Sollo, F. W., Jr., "The Mechanism of the Methane Fermentation." *Jour. Amer. Chem. Soc.*, **70**, 1778 (1948).
37. Liebmann, H., "Zur Biologie der Methanbakterien." *Gesundh. Ing.*, **71**, 14 and 56 (1950).
38. Hiss, P. H., Jr., "A Contribution to the Physiological Differentation of *Pneumonococcus* and *Streptococcus* and to Methods of Staining Capsules." *Jour. Exp. Med.*, **6**, 317 (1905).
39. McFarland, Jr., "The Nephelometer." *Jour. Amer. Med. Assoc.*, **49**, 1179 (1907).
40. Chick, H., "A System of Bacteriology in Relation to Medicine." Vol. 1, p. 179. H. M. Stat. Off., London (1930).
41. Buck, T. C., Jr., "A Modified Loeffler's Medium for Cultivating *Corynebacterium diphtheriae.*" *Jour. Lab. and Clin. Med.*, **34**, 582 (1949).
42. "Standard Methods for the Examination of Water and Sewage." 9th Ed. Amer. Pub. Health Assn., New York, N. Y. (1946).
43. Koser, S. A., "Correlation of Citrate Utilization by Members of the Colon-Aerogenes Group with Other Differential Characteristics and with Habitat." *Jour. Bact.*, **9**, 59 (1924).

MAKE YOUR HOTEL RESERVATIONS FOR THE FSIWA TWENTY-SIXTH ANNUAL MEETING

The Bayfront Park Auditorium at Miami, Florida, will be the headquarters for the Federation's Twenty-Sixth Annual Meeting, to be held October 13–16, 1953. An outstanding technical and social program is being planned for the four-day meeting.

Requests for room reservations should be addressed directly to the FSIWA Housing Committee, 320 N. Fifth St., Miami, Fla. (see page 1125 for details). It should be noted that the technical program will open on Tuesday morning, October 13, and will close at noon on Friday, October 16, but early arrivals may register on October 12.

WRITE NOW FOR YOUR RESERVATIONS!

APPLICATION OF OXIDATION-REDUCTION POTENTIALS TO THE CONTROL OF SEWAGE TREATMENT PROCESSES *

By Frederick E. Nussberger

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The treatment of sewage involves changes in the physical, chemical, and biological characteristics of the organic and inorganic matter dissolved and in suspension in the sewage. The activated sludge process and the modifications thereof accomplish these changes mainly by the biological action of the organisms comprising the activated sludge.

Certain tests, such as the biochemical oxygen demand test, can be used to determine and measure the changes which take place in the sewage before and after treatment. Other tests (such as quantitative chemical determinations of the free ammonia, nitrite-nitrogen, and nitrate-nitrogen content of the treated sewage) are used to define the extent of the biological oxidation that has been accomplished by the treatment. Still other tests, such as the various rate of oxygen utilization tests, differing mainly in the design of the apparatus used for the tests, are used to define the oxidizing power of a given activated sludge and the capability of the sludge to purify sewage at a high or a low rate.

All these tests have one factor in common: they all depend on the mechanism of the biological oxidation of the sewage.

The oxidation-reduction potential of the sewage describes the state of oxidation of the sewage according to the fundamental electronic concept of matter. This is a relatively new tool in the field of sewage treatment, although it has been used for many years by the biochemist and bacteriologist in studies of the mechanism of biological action.

This paper is concerned with studies made in the laboratories of the Department of Public Works of the City of New York during the past four years pointed towards the application of oxidation-reduction potentials to the better control of sewage treatment processes and increased efficiency and economy in operation.

Other studies describing the relation of oxidation-reduction potentials to sewage treatment and applications to the operation thereof have been published by Dickenson (1); Rohlich, Sarles, and Kessler (2); Moore, Ruchhoft, and Wattie (3); Moore and Ruchhoft (4); Rohlich (5); Eliassen (6); Hood (7); Dawson and Jenkins (8); Hood and Rohlich (9); Keefer and Meisel (10)(11); and Eckenfelder and Hood (12).

The present paper covers a means for determining the condition of a given activated sludge, a procedure for evaluating the performance of final sedimentation tanks of the activated sludge process, means for controlling the step aeration process of sewage treatment, and a detailed description of how the determinations were made.

In considering the oxidation-reduction potentials of sewage-activated sludge mixtures it is important to realize the implications of the fact that it is the organisms of the activated sludge, by processes of metabolism, which are responsible for the changes in the oxi-

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dation-reduction potential. For this reason, it is found that in a sample of a mixture of sewage and activated sludge which has been allowed to settle, the oxidation-reduction potential in the settled sludge layer quickly becomes less than the oxidation-reduction potential of the supernatant liquor. Furthermore, if such a sample, after having remained quiescent for an appreciable period, is stirred, the oxidation-reduction potential of the mixed sample is less than it was before sedimentation. Also, the dissolved oxygen is used up in the settled sludge layer at a greater rate than in the supernatant liquor; the oxidation-reduction potential of the settled sludge layer holding, however, at a relatively high level until the dissolved oxygen in the liquor of the sludge layer is used up and the organisms of the activated sludge begin to draw oxygen from the oxidized compounds which these organisms had previously manufactured in the liquor.

The practical point of the foregoing is that if it is desired to determine the oxidation-reduction potential of the settled sludge, care should be taken not to draw into the sample taken (as from a final sedimentation tank) any of the supernatant liquor, and if the oxidation-reduction potential of the mixed liquor is to be determined, the determination should be made quickly and without allowing the activated sludge to settle.

One might also point out that the standard test universally used to control the aeration stage of the activated sludge process (namely, the determination of the concentration of dissolved oxygen in the aeration tank liquor) does not give nearly so fundamental an insight into the effectiveness of the aeration as the oxidation-reduction potential of the aeration tank liquor, for the latter refers directly to the state of oxidation of the organic matter in the mixed liquor due to the activity of the organisms of the activated sludge. Furthermore, the dissolved oxygen concentration of the aeration tank liquor may be low, but nevertheless, effective purification may be indicated by the high level of the oxidation-reduction potential.

Condition of the Activated Sludge

In the activated sludge process of sewage treatment, the condition of the activated sludge with respect to its biological activity is a prime factor determining the degree of treatment that can be obtained. The fundamental nature of the oxidation-reduction potential enables it to be used to define the condition of the activated sludge.

In the past, various activated sludges have been characterized as "overloaded," "underloaded," "overoxidized," "underoxidized," "stable," or "unstable." It is important to know which characterization applies to the activated sludge of a particular plant at a particular time, because if this characterization can be made, remedial steps may be taken towards the development of a normal activated sludge.

In certain respects, if a sludge is overloaded, it may also be said to be underoxidized, or, if a sludge is underloaded it may be said to be overoxidized. Likewise, a sludge which is unstable may be overloaded or underoxidized, and a sludge which is stable may be underloaded or overoxidized.

The activated sludge process is remarkable in that it is a true "middle-of-the-road" process. Overloading, or underaeration, produces a sludge that is unstable and has poor settling qualities. Underloading, or overaeration, produces a sludge that is stable but shows evidences of disintegration and dispersal of the floc into fine pinpoint particles.

If a sample of aeration tank effluent is allowed to stand with stirring but without access to air, and the oxidation-reduction potential measured at regular time intervals is plotted against time, the rate of reduction curve obtained enables the particular activated

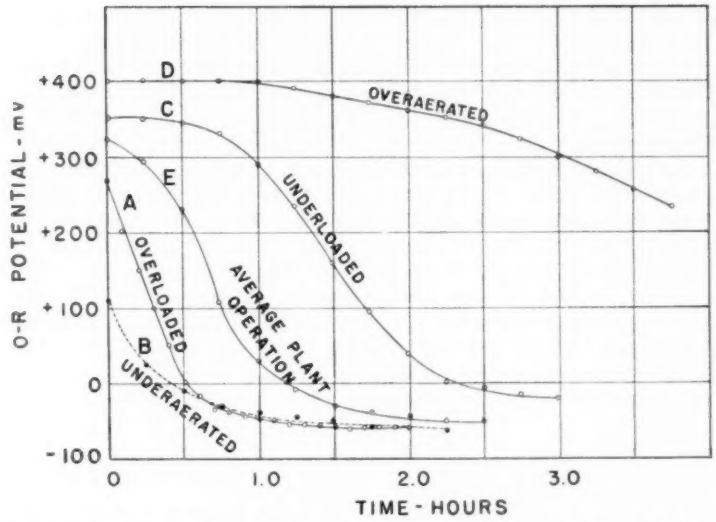

FIGURE 1.—Comparative reduction curves of various activated sludges, showing normal and abnormal conditions.

sludge tested to be characterized as overloaded, underoxidized, overaerated, or underloaded, as well as yielding other pertinent information regarding the purifying characteristics of the activated sludge. Aeration effluent is used in these particular tests because it is the end product of the aeration period.

Examples of the curves produced by various activated sludges are given in Figure 1, in which Curve A illustrates the rate of reduction curve obtained with a sample of aeration tank effluent in which the activated sludge was overloaded. The oxidation-reduction potential is seen to fall off rapidly, indicating a high concentration of unoxidized sewage solids in the presence of activated sludge solids and a definitely unstable sludge, which would quickly become septic if settled in a final sedimentation tank.

Curve B illustrates what happens when an underaerated activated sludge is held without aeration. Here the oxidation-reduction potential does not fall off as rapidly, mainly because the curve starts at a lower oxidation-reduction potential than in the case of the overloaded sludge. This sludge, after several recirculations in the system, would lose most of its ability to efficiently purify sewage.

Curve C illustrates an underloaded activated sludge. The initial oxidation-reduction potential is high and remains high for some time, after which the oxidation-reduction potential falls at a slow rate. Only after a very long time does it fall to a level comparable to that of the previous two curves.

Curve D shows an overaerated activated sludge; one which is high in nitrites and nitrates and which showed evidence of "burning" itself up. The curve starts at a high oxidation-reduction potential, and because of the reserve oxygen of the nitrites and nitrates the curve maintains a high level of oxidation-reduction potential.

The curves shown are representative of many such determinations made in connection with laboratory experimentation and plant operation.

Points on these curves which are significant and which should be capable of identification are: (a) the oxidation-

reduction potential at which the dissolved oxygen approaches zero concentration; (b) the oxidation-reduction potential at which the different oxidized forms of nitrogen disappear; and (c) the lower oxidation-reduction potential at which the sludge floc begins to disintegrate, as shown by the development of a turbidity in the supernatant liquor. Attempts were made to locate these points at definite oxidation-reduction potentials with some success, but more time and refinements in apparatus are required to establish them definitely.

Curve E illustrates an activated sludge that is normal for the Tallmans Island plant. The fairly high initial oxidation-reduction potential and the low initial rate of reduction would seem to indicate that the biological oxidation had proceeded satisfactorily. The extent to which the biological oxidation had been accomplished is indicated by the length of time (about 2 hr.) required to reach septic conditions at a potential of about −50 mv. The steep slope in the middle section of the curve indicates that the sludge was biologically very active.

It will be observed that some of the curves appear to approach a lower oxidation-reduction potential limit of about −50 mv. The lowest potential reached in an extended period of 24 hr. was about −250 mv. The important question arises as to what is the lowest oxidation-reduction potential to which an activated sludge may be reduced without losing its ability to clarify sewage. In plant operation the lowest oxidation-reduction potential would be reached during the detention of the sludge on the bottom of the final sedimentation tanks without access to a sufficient supply of dissolved oxygen. It is well-known that activated sludge should be returned to the aeration tank as quickly as possible, the rate of the return being limited only by the concentration of solids in the returned sludge and the required concentration of solids in the mixed liquor. Obviously, the lower the potential of the returned sludge, the greater the degree to which it has deteriorated, and the lesser the degree of purification of sewage which may be obtained by it during the aeration period. Obviously, too, the higher the oxidation-reduction potential of the aeration tank effluent the greater the reserve capacity of the sludge to resist deterioration in the final sedimentation tanks. The optimum operating potentials of the various stages of the activated sludge process have not, as yet, been definitely established.

The apparatus used in these tests is shown in Figure 2. The 1-l., wide-mouth bottle *A* is fitted with a rubber stopper *B*, having three holes through which are inserted a calomel cell *C*, a platinum electrode *D*, and a glass tube *E*. A magnetic stirrer *F* provides stirring by means of the magnetic bar *G*.

The bottle is filled with a fresh sample, the magnetic stirring bar is placed in the bottle, and the stopper is inserted

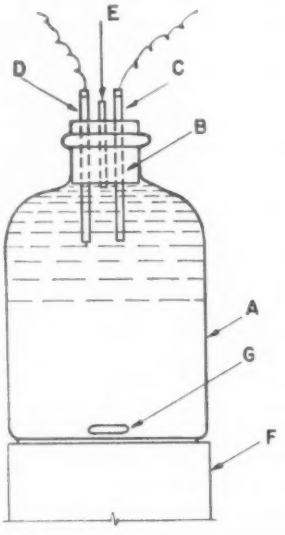

FIGURE 2.—Experimental apparatus used in determining changes in oxidation-reduction potentials in the absence of oxygen.

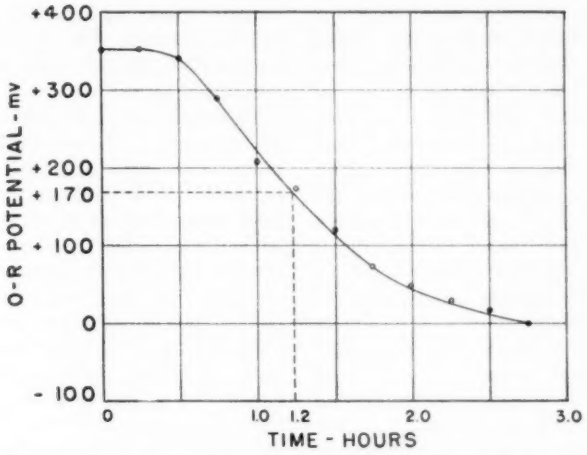

FIGURE 3.—Derivation of effective detention period from the oxidation-reduction potentials in final sedimentation tanks.

firmly, allowing the displaced liquor to overflow through the glass tube and without permitting air bubbles under the stopper. The stirring is begun and the leads to the electrodes are connected to a null-point potentiometer. The electrodes used were the Beckman calomel and platinum electrodes (5 in. in length). Meters used and found to be satisfactory were the Beckman Model G and the Hellige pH meters. Before using, the platinum electrode was cleaned by rubbing thoroughly with a slurry of Bon Ami and water, rinsing thoroughly, again rubbing with the Bon Ami slurry, followed by a second rinsing, and then placing the electrodes in water until the sample was obtained. Because of the continual biological activity taking place, it is essential that the determination be started as soon as possible after taking the sample.

Measurements of the oxidation-reduction potentials were made at 6′, 12′, or 15-min. intervals. Curves were then plotted of oxidation-reduction potentials vs. time. The oxidation-reduction potentials given are the potentials referred to the hydrogen electrode, E_h, expressed in millivolts.

Final Sedimentation

An interesting application of the rate of reduction curve is to the final sedimentation stage of the activated sludge process. The calculated detention period of the sewage in the final sedimentation tank is different from the detention period of the returned sludge solids. The procedure described here, however, may be used to estimate the detention period of the sludge in the final sedimentation tanks, because if it is found that the oxidation-reduction potential of the returned sludge is, for example, 100 mv. less than the oxidation-reduction potential of the aeration tank effluent, and the rate of reduction curve obtained on a sample of the aeration effluent showed a decrease of 100 mv. in 45 min., then the "effective detention period" of the sludge solids may be said to be 45 min.

The method of determining the effective detention period is shown in Figure 3. The curve shown is the rate of reduction curve of a sample of the aeration tank effluent, which had an initial oxidation-reduction potential of +350 mv. A sample of returned sludge taken directly from the sludge sump

of the final sedimentation tank by means of a bomb sampler was found to have an oxidation-reduction potential of +180 mv. The difference, or loss in potential between the aeration tank effluent and the returned sludge is +170 mv. and corresponds to 1.2 hr. as the effective detention period of the sludge in the final sedimentation tank.

It may be said that the objectives of the final sedimentation step of the activated sludge process are to produce a clarified effluent having a minimum concentration of suspended solids, and to collect and return an activated sludge with a minimum deterioration of the biologically active floc.

Final sedimentation tanks should be designed with these requirements in mind. The relative locations of the point of influent and the return sludge sump, and the means of mechanically collecting the settled sludge, merit special consideration.

One of the difficulties in judging the design of final sedimentation tanks of the activated sludge process has been the lack of a satisfactory tool for studying and evaluating the performance of these tanks. Such means as velocity and density current measurements, degree of concentration of the returned sludge, odor characteristics of the returned sludge, and quality of the effluent have been useful for evaluating the performance and efficiency of final sedimentation tanks.

Discussed here is another tool: the measurement of oxidation-reduction potentials. The oxidation-reduction potential of the influent liquor to the final sedimentation tank is compared with the oxidation-reduction potential of the settled and collected returned sludge. The magnitude of the deterioration of the activated sludge due its detention in the final sedimentation tanks is shown by the difference between the oxidation-reduction potentials.

The procedure is as follows: samples of aeration tank effluent and of returned sludge are taken at approximately hourly intervals. A bomb sampler is used to take the sludge sample from the sludge sump before the airlifts or sludge pumps. The measurement of the oxidation-reduction potential is made as soon as possible after sampling. Results obtained by this procedure during the evaluation of a final sedimentation tank are shown in Figure 4, in which the two curves show that the difference between the oxidation-reduction potentials of the aeration tank effluent and the returned

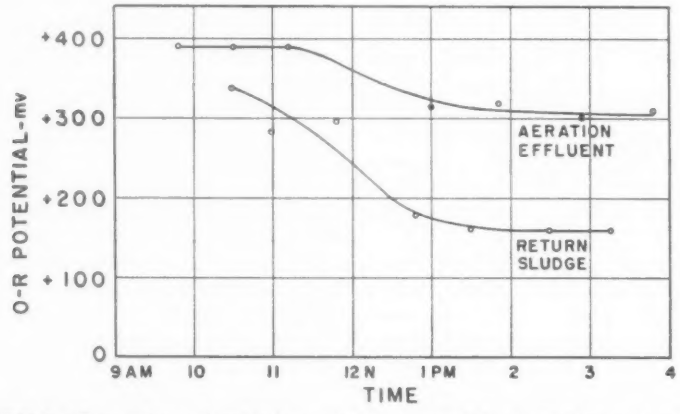

FIGURE 4.—Comparison of oxidation-reduction potentials of aeration tank effluent and return sludge at various times during the day.

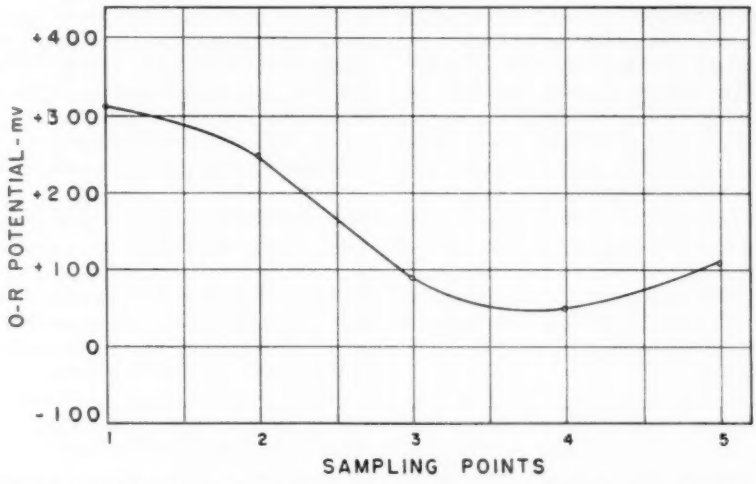

FIGURE 5.—Oxidation-reduction potentials of the bottom sludge in a rectangular final sedimentation tank.

sludge is about 80 mv. at 11 AM and about 140 mv. at 3 PM. These values represent the deterioration of the activated sludge at these times due to detention in the final sedimentation tanks without sufficient oxygen supply available to satisfy the oxidation rate of the sludge.

It will be observed that there is a greater difference in the 3 PM potentials than in the 11 AM potentials. This is usually the case. The detention period of the aeration tank liquor in the aeration tank is normally greater in the morning hours, due to the lower rate of sewage flow, and consequently the activated sludge reaches a higher state of oxidation. As the flow increases, the sludge is pushed out of the aeration tanks and accumulates in the final sedimentation tanks, as a result of which the period of detention (and deterioration) of the sludge in the final sedimentation tanks will be greater in the afternoon than in the morning. An additional factor is that the activated sludge of the aeration tank effluent is more heavily loaded with a more concentrated sewage in the afternoon than in the morning. Consequently, the activated sludge of the aeration tank effluent will be less stable in the afternoon.

If the performance of different final sedimentation tanks of different plants is to be compared it is necessary to consider the respective plant operating data (for example, the rates of returned sludges, the overflow rates, the concentrations of suspended solids in the returned sludges, the concentrations of suspended solids in the aeration tank effluents, the B.O.D. loadings, and the sludge indexes).

The corresponding operating data are important, because if the rate of return is increased, the period of detention of the activated sludge solids in the final tanks will be decreased. However, if the rate of return is increased to the point where overlying liquor is pulled, concentration of sludge is no longer attained. In this case, the measurement of the oxidation-reduction potential of the mixture will not be representative of the oxidation-reduction potential of the sludge layer because the reduction in potential caused by the biological activity of the organisms in the sludge is transmitted only to the liquor

in the immediate vicinity of the sludge solids, and the oxidation-reduction potential of the mixture will therefore be high, due to the mixture with the overlying liquor, which has a higher oxidation-reduction potential. A sludge with good settling qualities—that is, a sludge with a high sludge density index (S.D.I.)—may be returned at high concentrations and at a low rate of return. If the design of the final sedimentation tanks and the sludge collection mechanism is efficient, the decrease in oxidation-reduction potential should be small.

In a study of a rectangular final sedimentation tank, in which the sludge was collected at the end of the tank opposite to the influent, the curve shown in Figure 5 was obtained. The samples of bottom sludge taken for measurement of oxidation-reduction potential were taken with a bomb sampler at five points equally spaced between the point of influent liquor entry and the sludge sump. This curve shows the decrease in potential of the bottom sludge during sedimentation, compaction, and collection. The decrease is the result of the rapid utilization and subsequent depletion of the dissolved oxygen in the surrounding liquor by the organisms of the activated sludge and the subsequent biochemical reduction due to the biological activity in the absence of dissolved oxygen.

The curve shows clearly the progressive deterioration of the activated sludge in the final sedimentation tank. This deterioration is expressed quantitatively by the decrease in the oxidation-reduction potential of the sludge layer. Thus, there is provided a valuable tool for controlling the final sedimentation stage of the activated sludge process, for it may be used to control the rate of return of activated sludge from the final sedimentation tanks to the aeration tanks.

It will be noticed that there is an increase in oxidation-reduction potential at the end of the tank near the point of sludge withdrawal at the sludge sump. This is due to the disturbance of the sludge blanket caused by the pump suction and the consequent pulling in of overlying supernatant liquor with the sludge.

It is believed that measurements of oxidation-reduction potentials by a procedure similar to that described provides means for studying the performance of a final sedimentation tank of the activated sludge process, and also for comparing the performances of various designs of final sedimentation tanks with respect to size, shape, sludge collection mechanisms, methods of sludge return, and relative positions of influent, effluent, and sludge sumps.

Control of Activated Sludge Process

The activated sludge process involves biological oxidations of the organic and inorganic components of sewage, the extent of the various oxidations accomplished by the activated sludge being reflected in the oxidation-reduction potentials of the aeration tank liquor. Consequently, measurement of the oxidation-reduction potentials of aeration tank liquor can be used as a control in the activated sludge process.

In particular, it has been found to be especially valuable in understanding the operation and mechanism of the step-aeration modification of the activated sludge process.

The New York City Department of Public Works operates 14 sewage treatment plants. Eight of these plants employ the activated sludge process or modifications thereof and have facilities for step aeration (that is, the addition of raw or settled sewage at several points along the line of flow in the aeration tanks).

For the purposes of this paper, the results of the Tallmans Island and Bowery Bay plants are discussed. The Tallmans Island aeration tanks have four passes each, with provision for three points of sewage addition. The Bowery Bay aeration tanks have four

passes each, with provision for four points of sewage addition.

Figure 6 illustrates the direction of flow through the aeration tanks at both plants and the points of possible additions of sewage.

Step aeration is flexible in operation and may be carried out in any of several ways. For example, returned sludge, or returned sludge plus a portion of the sewage, may be added at the beginning of the aeration tank, and sewage may be added in desired proportions at any or all of the several possible influent points in the tank.

Obviously, one of the chief controls of the process is the volume of sewage to be added at the various points. It is understandable that this control may be difficult to most efficiently set up with the controls commonly at hand. An operation guide might be that the sewage added at any one point should be oxidized to a certain degree prior to the addition of another increment of sewage. To determine the degree of bio-oxidation of the sewage at any point in the tank, some form of apparatus that will measure the amount of oxygen used in the biochemical oxidation might be employed, or a procedure using the standard B.O.D. test might be adopted. Selected samples tested for dissolved oxygen and oxidized forms of nitrogen might also yield pertinent information. None of these tests, however, have the simplicity of the measurement of oxidation-reduction potentials. Neither can they be so readily used for control purposes.

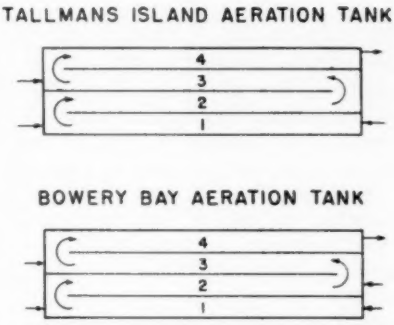

FIGURE 6.—Flow diagrams of the Tallmans Island and Bowery Bay aeration tanks, showing the points of admission of return sludge and sewage increments when employing step aeration.

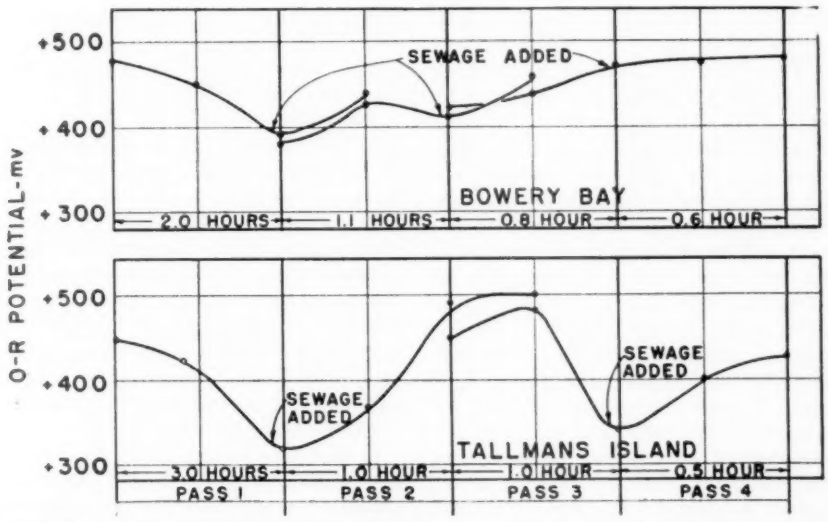

FIGURE 7.—Oxidation-reduction potentials through the aeration tanks at Tallmans Island and Bowery Bay when employing step aeration.

The use of oxidation-reduction potential measurements in determining the effect of incremental additions of sewage to the flow in the aeration tank and the oxidation-reduction potential curve obtained by pacing the flow through the aeration tank is shown in Figure 7.

It is important to note that in step aeration the rate of flow through the tank increases in subsequent passes after the addition of each increment of sewage. A rapid recovery in oxidation-reduction potential after comparatively short periods of aeration in the later passes of the tank is worthy of note and is well demonstrated in the curves.

The lower curve in Figure 7 shows the oxidation-reduction potentials of the Tallmans Island aeration tank liquor at times corresponding to the flow as it passed a number of stations along the line of flow. These stations were located at the beginning and middle of each pass and at the end of the last pass. On this particular day the aeration tank was operated so that the returned sludge only entered at the beginning of pass 1, an increment of settled sewage was added at the end of pass 1, and an additional and equal increment of settled sewage was added at the end of pass 3.

The effect of this split addition of sewage on the tank liquor is shown by pacing the tank liquor from the halfway point in the preceding pass. Also shown is the oxidation accomplished by aeration subsequent to the addition of sewage in the passes.

It will be noticed that the curves do not show a precipitous decrease in oxidation-reduction potential at the point where sewage is added. This is because in step aeration the sewage is added at the end of a pass and is directed with appreciable velocity upstream in the pass. The effect of this backflow of sewage in the pass is to depress the oxidation-reduction potential of the mixed liquor for a considerable distance upstream.

This is also the reason the curve showing the effect of aeration on the liquor in the first pass shows a decrease and not an increase in oxidation-reduction potential as would be expected. Returned sludge entered at the beginning of the first pass and a portion of the sewage entered at the end of the same pass. The volume of sewage added at this point was about twice the volume of returned sludge; consequently, there was an appreciable amount of backflow of sewage in the pass.

It is particularly interesting to note that in the step-aeration process the detention period, and consequently the period of aeration in the respective passes, is different.

It is possible to plot the curves in Figure 7 in two different ways. For example, the flow through the aeration tank may be looked at as a stream, to which different sewages are added tributary-wise. Then the potentials of the samples paced from the influent to the effluent end of the aeration tank would give a continuous curve.

It is also possible to plot the curves in a different way, bearing in mind that at any one instant the same sewage is added to the aeration tank at two different points. In this case, the curves would have to be discontinuous, because in effect the same sewage is added to two different streams in the aeration tank, one starting at the influent end of the tank and the other starting at the point where an earlier sewage had been added. In this way, the effect of the aeration on the same sewage may be shown in terms of oxidation-reduction potentials. To plot the curves in this way, it is necessary to time the sampling so that the samples are paced, beginning at these two starting points and reaching the two points where sewage is added at the same instant.

It will be observed from the curves that the dips in oxidation-reduction potentials caused by the additions of sewage were overcome by the subsequent aeration periods. This shows

that the sewage was biologically oxidized and that clarification was accomplished.

The value of the oxidation-reduction potential of the aeration tank effluent was +430 mv., which indicates a fairly high level of oxidation. In this connection it may be mentioned that the highest potential developed after prolonged aeration of the aeration tank liquor in a laboratory experiment was found to be about +550 mv., at which value the activated sludge showed definite indications of being overoxidized.

The upper curve in Figure 7 shows oxidation-reduction potentials obtained by pacing the aeration tank liquor through the aeration tank of the Bowery Bay plant. The curve shown was obtained when returned sludge was added to the first pass and sewage was added to the end of the first pass, to the end of the second pass, and to the end of the third pass.

Similar conclusions may be drawn from this curve as for the former curve.

Summary

In summary, measurement of oxidation-reduction potentials provides a tool for control of aeration in the activated sludge process and the step-aeration process because of the following observed effects:

1. The oxidation-reduction potential of the aeration tank liquor is greater at the end of a pass than at the beginning of the pass, provided, of course, that the air ratio is sufficient.
2. Addition of sewage to aeration tank liquor depresses the oxidation-reduction potential of the tank liquor.
3. If the oxidation-reduction potential of the aeration tank liquor is depressed to a very low value by the addition of too large a volume of sewage, it may not recover in value during the subsequent period of aeration.
4. If the activated sludge is well oxidized, as shown by a high level of oxidation-reduction potential of the aeration tank effluent, the oxidation-reduction potential of the returned sludge will be high, other factors being equal.
5. Sewage increments may be so distributed among the several aeration tank inlets in the step-aeration process as to give increasing peak values of oxidation-reduction potentials through the aeration tank.
6. Oxidation-reduction potential measurements may be used to control the volume of the sewage added at each point in step aeration so that it will allow a recovery of oxidation-reduction potential in the subsequent period of aeration to a value slightly greater than that prevailing before the addition of the sewage.

References

1. Dickenson, D., "The System Activated Sludge-Oxygenated Water. V. Changes in Oxidation-Reduction Potentials Within the Sludge Floc." *Jour. Soc. Chem. Ind.*, **59**, 257 (1940).
2. Rohlich, G. A., Sarles, W. B., and Kessler, L. H., "Oxidation-Reduction Potentials in Activated Sludge." A Symposium on Hydrobiology, p. 288, Univ. of Wisconsin Press (1941).
3. Moore, W. A., Ruchhoft, C. C., and Wattie, E., "Oxidation-Reduction Studies. I. Oxidation-Reduction Potentials Developed by Pure Cultures in Sewage." *Sewage Works Jour.*, **14**, 5, 980 (Sept., 1942).
4. Moore, W. A., and Ruchhoft, C. C., "Oxidation-Reduction Potentials Developed in Sewage and Sewage-Activated Sludge Mixtures." *Sewage Works Jour.*, **15**, 5, 880 (Sept., 1943).
5. Rohlich, G. A., "Oxidation-Reduction Potential Measurements in Activated Sludge and Activated Sludge-Sewage Mixtures." *Sewage Works Jour.*, **16**, 3, 540 (May, 1944).
6. Eliassen, R., "Oxidants and Reductants in Sewage Plant Effluents and Streams." *Water Works and Sewerage*, **92**, R-211 (1945).
7. Hood, J. W., "Measurement and Control of Sewage Treatment Process Efficiency

by Oxidation-Reduction Potential." *Sewage Works Jour.*, **20**, 4, 640 (July, 1948).

8. Dawson, P. S. S., and Jenkins, S. H., "The Oxygen Requirements of Activated Sludge Determined by Manometric Methods." *Sewage Works Jour.*, **21**, 4, 643 (July, 1949).
9. Hood, J. W., and Rohlich, G. A., "Oxidation-Reduction Potentials in Sewage Treatment." *Water and Sewage Works*, **96**, 352 (1949).
10. Keefer, C. E., and Meisel, J., "Activated Sludge Studies. I. Effect of Sludge Age on Oxidizing Capacity." THIS JOURNAL, **22**, 9, 1117 (Sept., 1950).
11. Keefer, C. E., and Meisel, J., "Activated Sludge Studies. II. Efficiency and Performance Under Various Operating Conditions." THIS JOURNAL, **22**, 12, 1518 (Dec., 1950).
12. Eckenfelder, W. W., and Hood, J. W., "Application of Oxidation-Reduction Potential to Biological Waste Treatment Process Control." Proc. 6th Purdue Indus. Waste Conf., p. 221 (1951).

GOLDEN, COLORADO, PLANT HAS NOVEL FEATURES

Some novel concepts of sewage treatment are embodied in the new plant placed in operation on August 1, 1953, at Golden, Colorado. The plant is designed to process the wastes of both the city of Golden and the brewery located there, as well as providing reserve capacity for 100 per cent expansion by both.

The essential novelties of the new plant include aeration and coagulation and settlement in the same tank, using concentric baffles (Figure 1); concentration of sludge from 2 to 10 per cent solids previous to digestion; and thermophilic digestion (130° F.) The theories involved are based on pilot plant tests. Digester gas is to be used for heat and power. Digested sludge is to be utilized for fertilizer. The compactness of the plant units is a major feature.

FIGURE 1.—Compact new sewage treatment plant at Golden, Colorado, combines aeration and settling in the same tank (foreground) and digests sludge at thermophilic levels (130° F.) in the two digesters (background).

THE PORTLAND SEWAGE TREATMENT PLANT *

By John W. Cunningham

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Portland, Ore., is most fortunate in being able to discharge its sewage effluent into one of the large rivers of the country, the Columbia. With storage regulation being provided on its headwaters, the Columbia will seldom have a flow below 100,000 cu. ft. per sec. and, unlike most streams, this low-water period is in very late fall or early winter when the objectionable features of pollution are reduced. Floods come in late spring or early summer, and the flow through the summer season is 150,000 to 200,000 cu. ft. per sec. Not only does the Columbia River provide ample dilution, but it also comes to Portland with a saturation of dissolved oxygen. From the Portland outfall to the Pacific Ocean is a river distance of 100 mi., with no use made of the water where sewage pollution is an important consideration.

Under these circumstances, the function of the Portland intercepting sewer system is mainly the transfer of sewage effluent from the much smaller and more highly polluted Willamette River to the Columbia. The treatment of this sewage before discharge into the Columbia has slight justification from the economic or public health standpoint, but meets with general public approval as a matter of good municipal housekeeping. The aim of the designers of the plant was to provide an acceptable treatment at minimum first cost and minimum cost of operation. Comparative figures show how well the first objective was attained, and experience to date indicates that the plant when fully loaded will be an exceptionally easy one to operate and maintain.

The Portland plant (Figure 1) provides primary treatment by sedimentation and separate sludge digestion. There are several unusual design and construction features. The process, however, is unusual only in the disposal of the digested sludge, which under control and on favorable river stages will be discharged into the outfall and thence into the Columbia. This feature has been the subject of serious study and much discussion. The justification is that the digestion process completely changes the character of raw sewage sludge, greatly reducing its volume, pathogenic organisms, and oxygen demand. The unsightly elements which characterize raw sewage are destroyed. Digested sludge is uniform and flocculent in character; it does not form putrefactive sludge banks, but is rapidly dispersed in water. This method of sludge disposal is not one for wide application, but is peculiarly adapted to the large volume and relatively swift current conditions in the Columbia. No visual observation or tests will disclose the presence of sludge in the river.

Design Basis

Portland's sewers are practically all of the combined type. One of the design problems for the intercepting sewer system was to divert some margin above the dry-weather or sanitary flow and allow the storm surplus to by-pass into the river. This has been done with special orifice-type regulators, described by Stevens and Thompson (*Sewage Works Jour.*, **20**, 2, 185; Mar., 1948).

* Presented at 1952 Annual Meeting, Pacific Northwest Sewage and Industrial Wastes Assn.; Portland, Ore.; Oct. 23–24, 1952.

FIGURE 1.—General view of Portland, Ore., sewage treatment plant with grit house and administration and laboratory building at right, settling tanks at upper left, and digesters in foreground. Trenches are for installation of sprinkler system.

The periods of overflow will be about 4.5 per cent of the time for the 52 sewers discharging into the Willamette and 3 per cent of the time for the 10 sewers discharging into a slough paralleling the Columbia River and known as Columbia Slough. The capacity of intercepting sewers and of the treatment plant is about 2½ times the dry-weather flow.

As a basis for designing the intercepting sewers and the treatment plant, periodic actual flow measurements were made for most of the sewer outfalls. For each district an estimate was made of the present population and resulting sanitary flow, industrial wastes, and infiltration. Then the future population, land use, and corresponding increment of flow was estimated. The resultant figures, by summation, gave outfall sewer and treatment plant capacities, which have only an indirect relationship to population. However, the Portland plant capacity is generally related to a population of 375,000. The design capacities are:

Minimum sanitary flow	40 m.g.d.
Average sanitary flow	60 m.g.d.
Maximum sanitary flow	75 m.g.d.
Maximum storm flow	155 m.g.d.

Studies indicate that the sewage should reach the plant in a reasonably fresh condition, with little or no hydrogen sulfide content, and an average strength somewhat less than normal. Sludge handling facilities at the plant are based on 200 p.p.m. of suspended solids in the raw sewage. The B.O.D. is not a factor, but will probably average about 200 p.p.m.

Treatment Units

The successive units in the treatment process are as follows:

1. Screening. Manually-cleaned coarse racks with 4-in. openings remove heavy material, followed by mechanically-raked bar screens with 1-in. openings. Screenings are sorted, shredded, and returned to the influent.

2. Grit removal. Controlled flow in trapezoidal grit channels gives about 1 ft. per sec. velocity. Grit is mechani-

cally removed, elevated, and disposed of with or without washing.

3. Sedimentation. Rectangular tanks provide 1.5-hr. detention at average rate with conventional longitudinal and cross collectors. Tipping-trough devices remove the scum, which is decanted to remove surplus water and the concentrated scum is dumped into the sludge well.

4. Sludge transfer. Visible sludge drawoff from the primary tanks is by telescopic pipes. Air-operated ejectors pump the sludge to preheating tanks, where it is heated by live steam to digester temperature and seeded with actively digesting sludge. Another set of ejectors then automatically pump the sludge from the preheating tank to the chosen digester.

5. Sludge digestion. Digestion is carried out in four 90-ft. diameter digesters with 720,000-cu. ft. total capacity. Three have floating covers, the fourth a gas-holder cover. Piping permits flexible arrangement, in stages as desired. Supplemental heat is added by injecting live steam into recirculation loops.

Sludge and Scum Concentration

The designers of the Portland plant have believed that most plants lose digester capacity by introducing raw sludge having too low solids content. In this connection, methods of intermittent sampling of sludge are quite unsatisfactory. A common practice is to start the sludge pump and guess at the time to shut it down. Also, the tendency is to pump sludge too fast, resulting in "coning" in the hoppers and drawing in sewage from above. The only certain way to control sludge quality is by visible and controllable discharge. In this plant telescopic discharge pipes (Figure 2) were used, actuated by hand wheels, with dis-

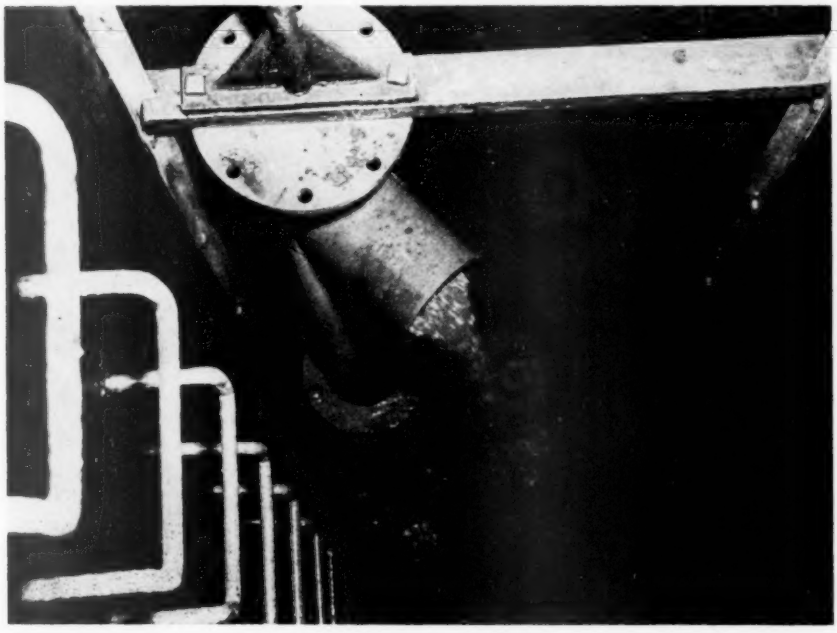

FIGURE 2.—Telescopic sludge drawoff allows visible control of sludge quality for transfer to digesters.

charge into a sludge well feeding the ejector. When the plant is in full operation, sludge will be drawn continuously from the settling tanks, with the visible sludge spouts set to give a steady dribble of heavy sludge.

A similar principle is observed in the concentration of scum. This is skimmed from the tanks by use of the ordinary tipping trough devices (Figure 3). Necessarily, a considerable excess of water (sewage) is collected along with the scum. This flows through pipes to the inlet end of the settling tanks and into decantation wells adequate in size to hold one average skimming from six collector bays. Allowing sufficient time for the scum and grease to rise to the top, a decantation pump is started and removes the liquor below the scum, with visible discharge leading back to the inlet channel. When scum appears, the pump is stopped and a gate is opened, dumping the concentrated scum and grease into the sludge well. The method of handling sludge and scum is shown in Figure 4.

Ejectors Used for Sludge Transfer

All pumping of raw sludge at the Portland plant is done by air-operated ejectors. A pair of ejector pots are located at the inlet end of each group of settling tanks. As fast as the raw sludge is drawn off, or the thickened scum is dumped into the sludge wells, it flows into the ejectors. When filled, these automatically pump it to the preheating and seeding tank. After a short period of detention for heating and mixing, it overflows into a second set of ejector pots, which in turn force it into any one of the digesters.

There are several reasons for using ejectors instead of other types of sludge

FIGURE 3.—Tipping-trough skimmers remove scum after it has been concentrated by fan-shaped water sprays.

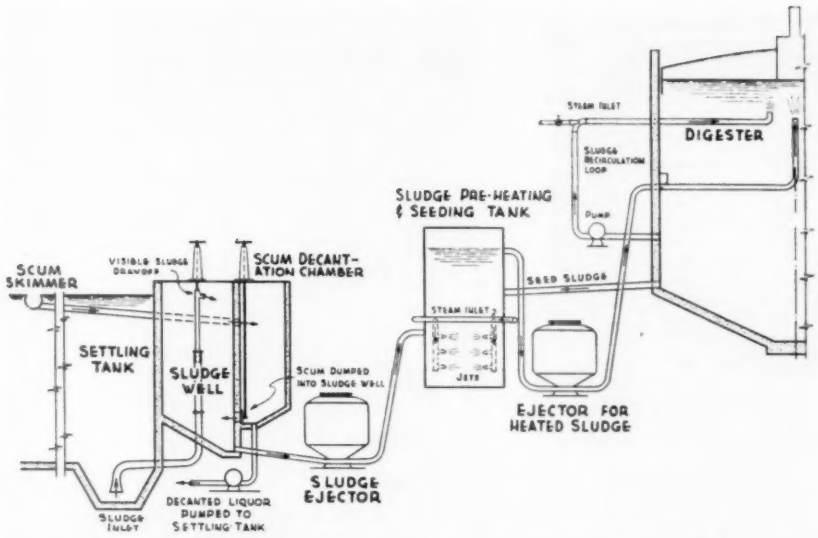

FIGURE 4.—Flow diagram showing method of handling sludge and scum.

pumps. They are completely automatic, with variable capacity, moving the sludge as fast as the pots are filled, and they operate perfectly in connection with the plan of manually controlled and visible sludge withdrawal. They have large waterways and valves, and are the most nearly clogless pumping device available. They are enclosed, odorless, and require a minimum of maintenance, as they have few moving parts. The over-all efficiency is low, which is a valid objection to large ejector installations handling sewage, but is unimportant with the relatively small volumes of sludge.

Compressed air for operating the ejectors is furnished by a pair of reciprocating compressors in the digester control house. These also provide air for other plant services.

Sludge Heating by Direct Steam Injection

All sludge heating at the Portland plant is done by direct injection of live steam produced in two large, gas-fired, sectional, low-pressure boilers. Steam from the same source also is used for heating the various buildings. Steam has for many years been used for process heating in the chemical and other industries, yet sewage plant designers have been slow to adopt this method, which is simple, cheap, and effective.

The sludge preheating tank is a vertical steel tank with an open top. It receives the discharge from two sets of ejectors, along with a steady, controlled flow of actively digesting sludge from one of the digesters, which is withdrawn for seeding purposes. The steam is introduced through a ring of nozzles at the bottom of the tank, accomplishing a thorough mixing, as well as heating the contents to digester temperature. An objectionable rattle or thump was expected, coming from collapse of the steam bubbles, and provision was made for introduction of a small amount of compressed air along with the steam to cushion the bubbles. However, in operation the noise has not proven excessive and these measures have been found unnecessary.

Sludge is recirculated in the digesters, or transferred from one digester to another by non-clog type centrifugal

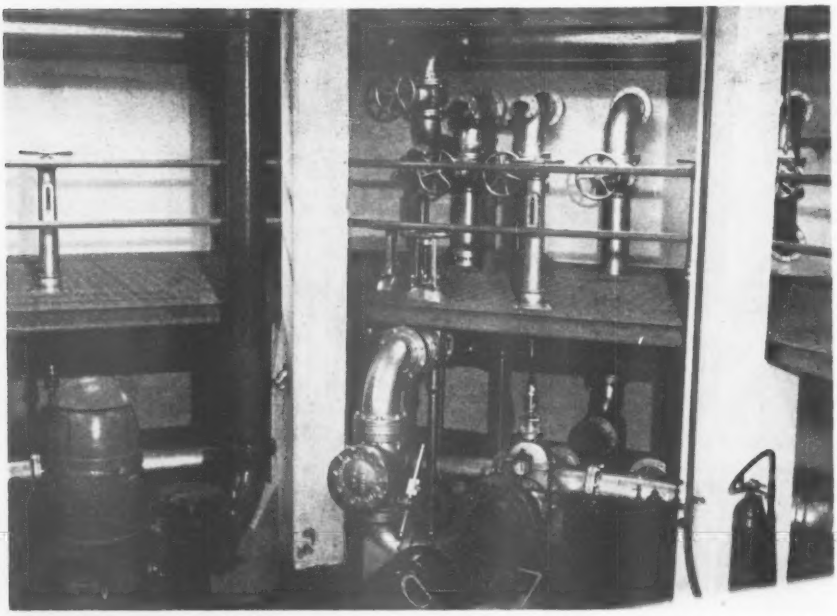

FIGURE 5.—One set of digester controls on upper deck, with recirculation pump below. Deep well pump at lower left is for plant (non-potable) water supply.

FIGURE 6.—Close-up of one set of digester controls, showing steam piping (black) with nozzles discharging into recirculation loops.

pumps. The circulating sludge passes through external pipe loops in the control house (Figure 5). Additional steam for maintaining digester temperature is injected through nozzles into elbows in these loops (Figure 6). Here again, considerable noise was expected, but did not materialize. Through nearly a full year of operation the sludge heating provisions at this plant have proven entirely adequate and satisfactory. For subsequent plants the same designers have eliminated the recirculation pumps, depending entirely on injection velocity of the steam and thermo-siphon action in the loops to secure circulation.

One limitation and problem in connection with direct steam heating should be recognized. All water converted to steam must be made up, and all solids are precipitated in the boilers as scale. This may necessitate pretreatment and softening of water in hard-water regions. The Portland water is very soft, with only 10 p.p.m. of solids, and forms a soft scale that is removed by blowing off the boiler.

Design of Digesters

Expiration of the Downes patents on floating covers for digesters has opened up this type for free use by the profession. The designers of the Portland plant recognized certain advantages in floating covers, and used them for three of the four units. For the fourth, a single-lift gas-holder roof was used, with a capacity of 80,000 cu. ft. to equalize the gas production and use in the plant. A complete structural analysis and design was made for the floating covers and the gas-holder cover. The floating covers depart from the customary Downes design in one particular. Instead of depending entirely on rim support when the tank is empty and the cover is not floating, there is also a central support from a concrete tower, which also carries various piping and appurtenances. This modification reduces stresses in the trusses and cylinder. Furthermore, it was found to greatly facilitate erection, which was accomplished entirely without falsework.

The gas dome on the fourth digester likewise was an original design from the structural and mechanical standpoint, although it followed practices current in the gas industry. With structural designs complete, the bidding for fabrication and erection of both the floating covers and gas dome was between structural shops, some of them local. The competition evident in the five bids received certainly saved the municipality a substantial sum of money.

Structurally, the concrete digester walls are of conventional design, using hoop steel, welded at laps, with a unit stress of 12,000 lb. per sq. in. Careful consideration was given to various methods of prestressing, but no substantial advantage or money saving was found. Any reduction in weight of reinforcement due to higher unit stresses is offset by the higher cost per pound of the prestressed bars or wire in place. Although proprietary designs offered showed reduced concrete yardage, due to cutting down on concrete wall thickness, with no reduction in form area the reduction in total cost was not important. The additional mass of concrete in the lower part of the digester walls was considered an advantage from the insulation standpoint. Above ground, the walls were further insulated by an air space and a masonry wall of hollow, light-weight concrete blocks.

Ventilation and Odor Reduction

The Portland water supply is soft and carries very little sulfates, and the sewage temperature is relatively low. Serious odor troubles were not anticipated. Nevertheless, every effort was made to reduce odors about the plant, particularly inside the structures. In the grit and screen house the bar screens are completely enclosed, with

fans of large capacity mounted above the enclosures and exhausting through the roof. The elevators of the grit collectors, which are inside the building, are likewise completely enclosed, with stacks leading to wind-action ventilators above the roof.

In the sludge transfer buildings, the sludge wells and telescopic sludge drawoff pipes are covered, with hinged lids for observation and fan ventilators creating an inflow of air at these openings, with exhaust through the roofs. A power ventilator was provided to exhaust air from the pipe tunnels at the inlet end of the sedimentation tanks. It has been very effective in keeping the tunnels fresh and dry.

The hazard from gas escape in the digester control house was recognized. The two boilers were located in separate rooms, with outside entrances only, louvre air intakes, and gravity ventilators in the roof. Gas piping, appurtenances, and controls were, as far as possible, concentrated in one room, with similar ventilation. The large basement control room, where gravity ventilation was impossible, has three separate blowers to discharge fresh air near the floor, and two large gravity ventilators to exhaust through the roof.

Plant Cost

The major items of piping, valves, and equipment for the Portland plant were purchased directly by the city and turned over to the contractor for installation. This plan makes more work for the engineers in connection with writing of specifications, purchase, and inspection of equipment and supervising installation. However, experience shows that it gives much more satisfactory results and lower over-all costs. It is good public policy to make equipment specifications fairly open to secure wide competition from suppliers. Under such open specifications there are bound to be variations in quality and suitability of equipment offered. With direct purchasing there is an opportunity for a certain amount of selection, weighing quality against price. On the other hand, when equipment is furnished through the general contractor it will certainly be the cheapest which will barely meet the specifications. In summary, the cost of the Portland treatment plant was as follows:

Site	$ 56,000.00
Equipment, purchased by city	314,815.52
Gen. contract and equip. install.	956,671.03
Minor contracts	23,873.50
Total	$1,351,360.05

These cost figures may be boiled down to unit costs of $21.59 per m.g. average sanitary flow, or $3.44 per capita, exclusive of site. These low costs for a primary treatment plant are something of a record for work done under postwar price levels. It must be conceded that the omission of sludge drying and effluent chlorination facilities represented substantial savings by comparison with many other plants. However, even with due allowance for these differences, the cost is still exceptionally low.

Acknowledgments

The entire Portland intercepting sewer system, including the pumping stations, and the treatment plant, involving a total cost of approximately $17,000,000, were designed by the firms of Stevens and Koon and John W. Cunningham and Associates, as a joint venture. The work was administered by a Consulting Board made up of Ben S. Morrow, R. E. Koon (succeeded later by J. C. Stevens), and the writer. A. M. Rawn was a special consultant on many features of the work and first suggested the adopted method of sludge disposal. The engineer in charge of construction was Gordon Burt, and the General Contractor was L. H. Hoffman.

PROTOZOA AS INDICATORS IN ACTIVATED SLUDGE TREATMENT *

By S. Baines,† H. A. Hawkes, C. H. Hewitt, and S. H. Jenkins

Respectively, Biologist, Biologist, Chief Assistant Chemist, and Chief Chemist, Birmingham Tame and Rea District Drainage Board, England

Early in the history of activated sludge it was recognized that the types of protozoan fauna associated with the sludge afforded a useful indication as to its condition. Four conditions and the associated protozoa were listed by Lockett (1a) (1b). These ranged from poor conditions when flagellates and rhizopods were dominant, ciliates being rare, to good conditions when the ciliates were dominant and restricted in species, and the flagellates and rhizopods were rare.

These observations were confirmed by Barritt (2) and Barker (3), who developed sludges under controlled conditions. Horasawa (4) classified the protozoa in activated sludge into three types. A poor sludge contained the free swimming type of protozoa which obtain their nutrient from materials in suspension or solution, an intermediate sludge being characterized by the presence of protozoa able to swim freely as well as creep and which obtain their food both from materials in suspension and from materials absorbed on the surface of the floc. A good sludge was typified by the dominance or organisms of sessile or creeping habit. Reynoldson (5) put these observations on a quantitative basis by showing that in the Huddersfield activated sludge the numbers of *Vorticella* present were related inversely to the oxygen absorbed 3-min. value and the 5-day B.O.D. of the effluent.

The work described in this paper was begun in order to see if a similar relationship could be observed at the Coleshill works of the Birmingham Tame and Rea District Drainage Board.

Intensive work was first carried out for one month, during which daily counts of the total peritrichous ciliates and total free-swimming ciliates were compared with the B.O.D. and the O.A. (oxygen absorbed from permanganate in 4 hr.) of the effluent. Later, biweekly counts were carried out for more than a year. These counts were made on the different dominant genera of the peritrichous and free-swimming ciliates in order to try and relate protozoan populations with a number of environmental conditions. These observations were made on a plant operating under normal conditions. Although this may make the results more difficult to interpret, it enables a proper assessment to be made of the value of protozoa as indicators in works practice.

During the intensive part of the work free-swimming forms (telotrochs) of *V. campanula* were observed. They were more numerous in samples that had been stored for some time, in which it was assumed the oxygen concentration had thereby been reduced. The effect of aeration on telotroch formation was, therefore, investigated under laboratory conditions.

Methods

The sewage treated at Coleshill is of a domestic nature, with occasional flushes of industrial wastes. After

* Presented at Twelfth Congress, International Association of Limnology; Cambridge, England; August 25, 1953.

† Currently at University of Birmingham, England.

TABLE I.—Operating Conditions at Unit I, Coleshill Works

Item	Av.	Min.	Max.
Sewage flow (m.g.d.):			
Imp.	3.62	—	—
U. S.	4.34	—	—
Sludge returned (m.g.d.):			
Imp.	1.2	—	—
U. S.	1.43	—	—
Detention time (hr.):			
Without sludge	6.5	—	—
With sludge	8.7	—	—
Solids in aeration tanks (p.p.m.)	1,314	406	1,520
Vol. matter in sludge (%)	85.8	—	—
Sludge index, 1 hr.	351	—	—
Air used (cu. ft.):			
Per Imp. gal.	0.83	—	—
Per U. S. gal.	0.69	—	—
Per sq. ft. of diffuser[1]	1	—	—
Ratio of diff. area to tank area[1]	1/10	—	—
B.O.D. aeration tank infl. (p.p.m.)	181	70	226
B.O.D. separating tank effl. (p.p.m.)	22.6	12	44
Sewage temperature (°C.)	12.6	5.0	18.8

[1] Approximate.

screening and grit removal it receives primary and secondary sedimentation. Between the primary and secondary tanks excess activated sludge is admitted and aerated for about 30 to 40 min. with the primary settled sewage. After secondary sedimentation the sewage is treated with activated sludge in two independent units, one consisting of 9 aeration tanks in parallel, the other of 9 similar tanks with 2 sets of 3 tanks operating in series, the other three in parallel. Details of operating conditions of the aeration unit not presented with the results are given in Table I. Further details are reported by Winsor (6).

Intensive Study

Samples were taken of mixed liquor from the last of the three aeration tanks in series and examined 2 or 3 hr. later. Using the cell of a haemocytometer 0.1 mm. deep, and by traversing an area of 10 mm. by 6.5 mm. measured on the microscope stage, five separate counts were made of both total peritrichous and total free-swimming ciliates in 6.5 cu. mm. of the shaken sample. As the numbers of peritrichous ciliates are closely associated with the amount of sludge, the numbers were expressed on the basis of 1,000 p.p.m. of suspended matter, determined on the samples used for protozoa counts. The effluent was sampled hourly throughout the day and its quality assessed using the B.O.D. and O.A. tests on the settled sample.

Extensive Study

Samples were taken twice each week from each unit and examined by similar methods. Daily, the dissolved oxygen contents of samples taken from the effluent end of the aeration tanks were determined after preserving the samples by the addition of copper sulfamic acid. Counts were made on the following individual genera: *Vorticella, Opercularia, Lionotus, Aspidisca, Euplotes, Oxytricha, Stylonychia, Colpidium,* and *Paramoecium.* As these, with the exception of *Colpidium* and *Paramoecium,* were found associated with the sludge flocs, they were expressed as numbers per unit weight of sludge. The aeration tank influent and

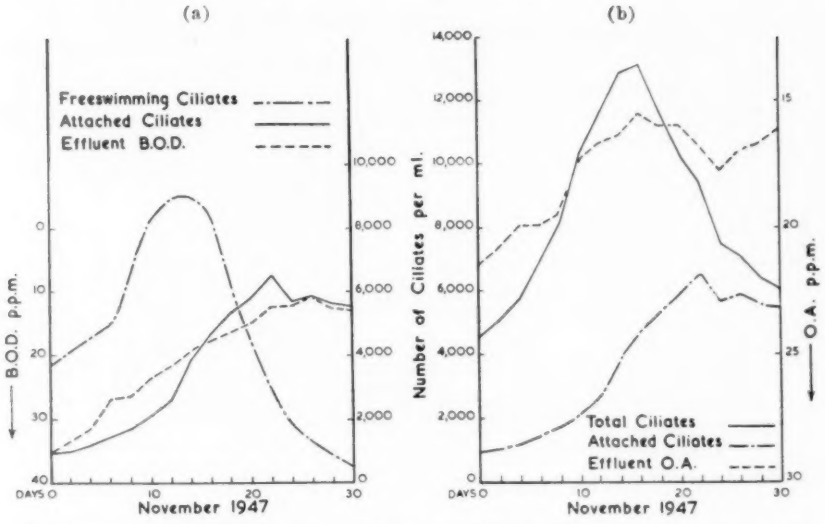

FIGURE 1.—Relationship between effluent quality and numbers of free-swimming, attached, and total ciliates.

effluent were sampled hourly throughout the day previous to taking the samples for protozoan counts and the B.O.D., O.A., pH, ammonia, and oxidized nitrogen were determined. Temperature and rainfall records were also kept.

Results and Conclusions

The results of the daily counts, expressed as numbers per ml. of sludge, for the month of February, 1947, are expressed graphically in Figure 1. To remove the unevenness in the curves, a system of moving averages was applied using a 5-day period. The B.O.D. and O.A. curves are inverted to facilitate comparison with the counts. Figure 1a shows that throughout the month there was a good inverse correlation between the numbers of peritrichous ciliates and the B.O.D. of the effluent; this, however, did not exist in the case of the free-swimming ciliates nor, consequently, for the total ciliates. Figure 1b shows that there was an inverse correlation between the peritrichous ciliates and O.A. values for the first part of the month, but not after that. However, there was an inverse correlation between the total ciliates and O.A.

The results of the extensive study on both units confirmed one another; therefore, only one set of results is presented. The results are shown as moving averages, using the average of three values for each point. Figure 2 shows the fluctuations in numbers of *Vorticella* spp. and *Opercularia* (Figure 2a), the free-swimming ciliates *Lionotus* and *Aspidisca* (Figure 2b), and the correlation between the total of these and the B.O.D. of the settled effluent (Figure 2c). Figure 2a shows that throughout the period *Vorticella* spp. and *Opercularia* became successively dominant and that the correlation between the quality of the effluent and the total of the peritrichous ciliates was closer than that for either of the genera separately. During the period of the investigation only two members of the free-swimming ciliates became sufficiently numerous to be considered. Figure 2b shows that the peaks of both *Lionotus* and *Aspidisca* usually

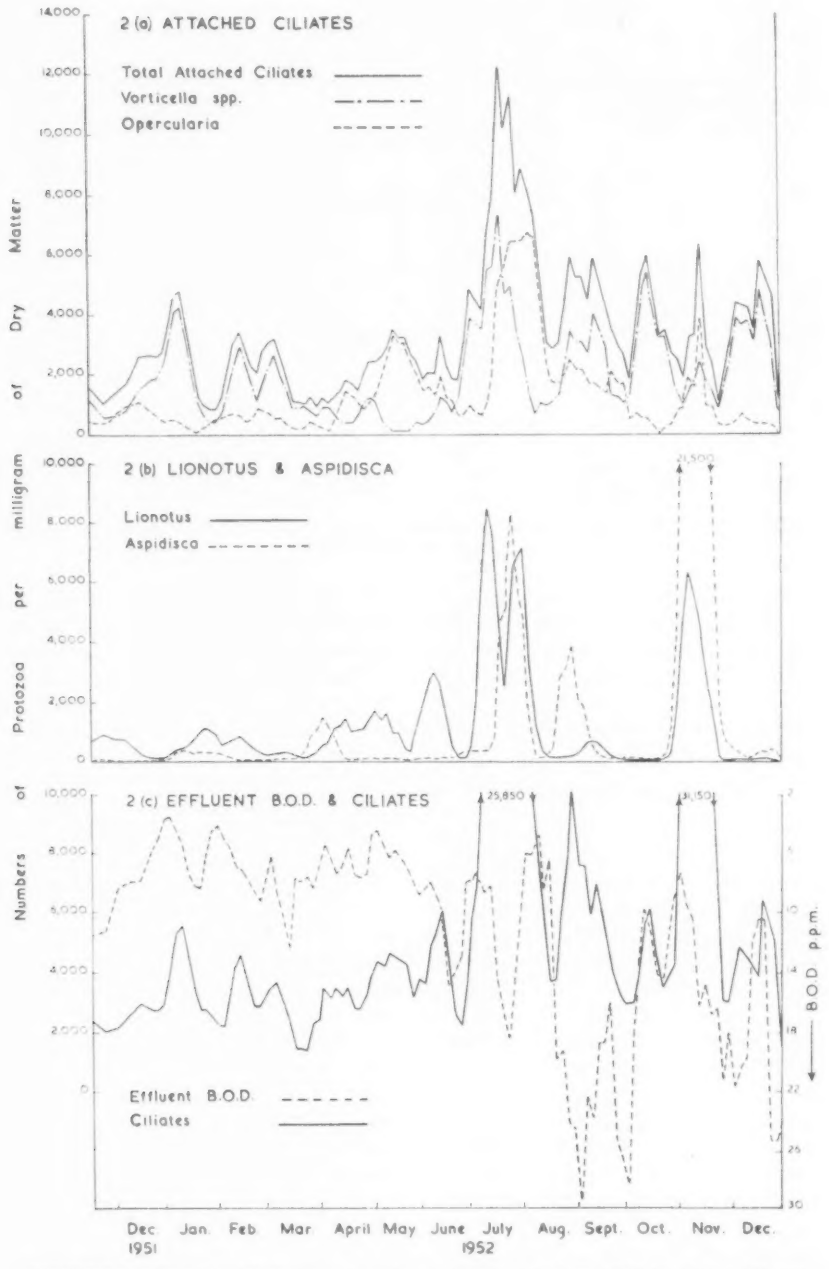

FIGURE 2.—Relationship between numbers of ciliates and the B.O.D. of the effluent.

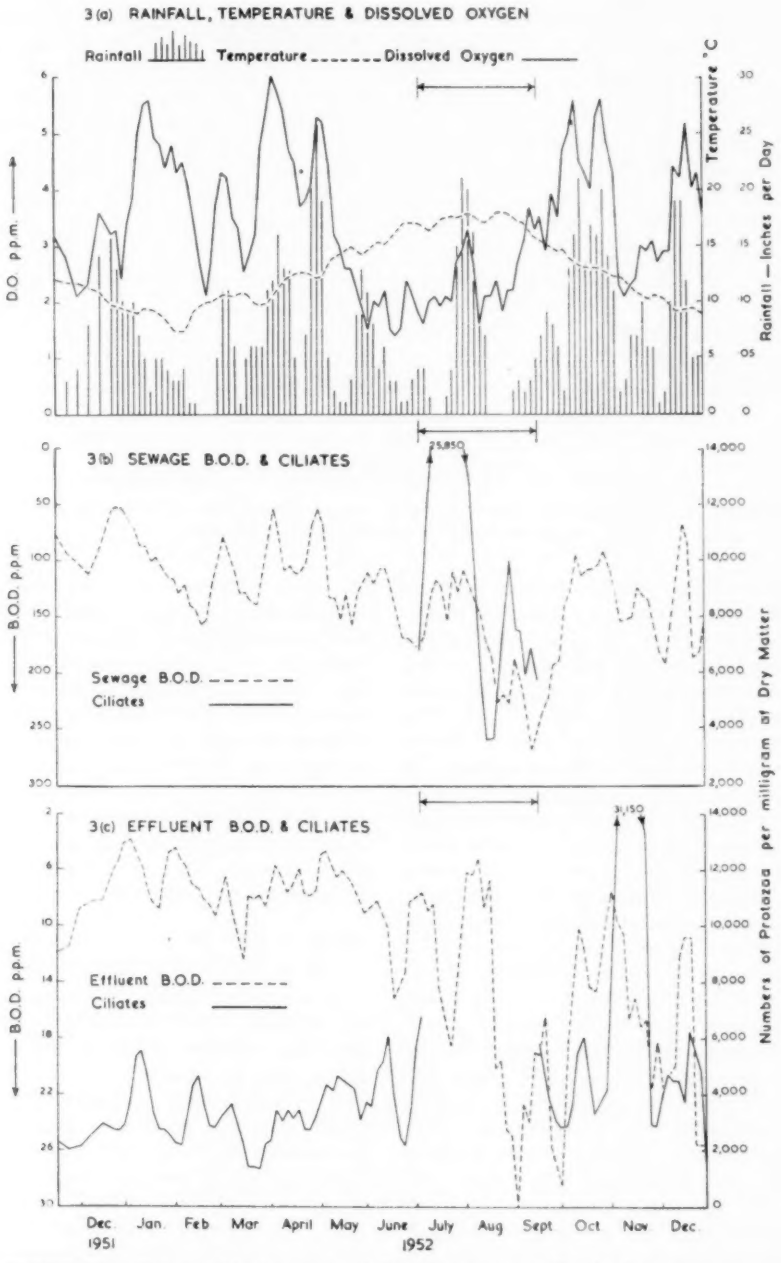

FIGURE 3.—Relationship between rainfall, temperature, dissolved oxygen, sewage strength, effluent quality, and ciliate population.

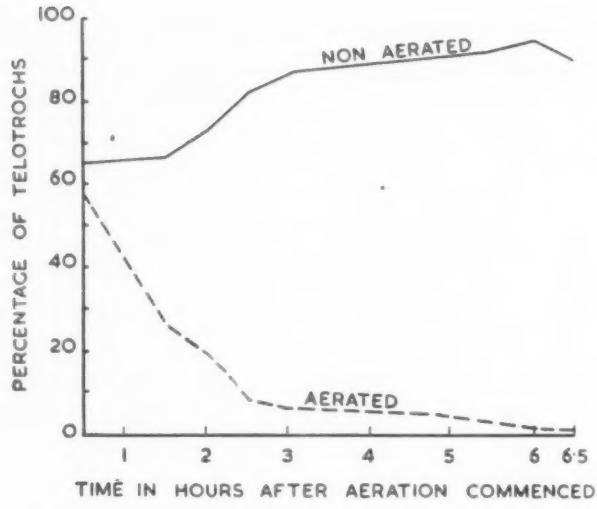

FIGURE 4.—Percentage of free-swimming forms (telotrochs) of *Vorticella campanula* in aerated and non-aerated activated sludge.

occurred in association with peaks of the attached ciliates. It seemed reasonable, therefore, to study the correlation between the total of the peritrichous ciliates plus *Aspidisca* and *Lionotus* and the quality of the effluent. Figure 2e shows that for most of the period there was some correlation, although in some cases, especially in the colder period, fluctuations in ciliate numbers lagged behind the corresponding fluctuations in the B.O.D. results. During the summer months, correlation was absent, as on occasions large numbers of ciliates in the sludge were not accompanied by a reduction in the B.O.D. of the effluent. These inconsistencies are discussed later.

Several factors might affect the ciliate populations. The pH range (7.1 to 7.7) was not considered to be sufficiently wide to be of importance. During the period of observations nitrification was negligible. Therefore, this factor also is not considered. The connection between rainfall, temperature, dissolved oxygen in the aeration tanks, sewage strength, and quality of the effluent is seen in Figure 3. Rainfall obviously influences both the dissolved oxygen and the sewage strength. Moreover the quality of the effluent is largely determined by the strength of the sewage. These factors might be related, therefore, to the ciliate population. Figures 3b and 3c show that for the period when there was lack of correlation between the ciliate population and the B.O.D. of the effluent, the ciliate population correlated with the B.O.D. of the sewage. During this period the temperature exceeded 15°C.

Effect of Aeration on Telotroch Formation of Vorticella campanula

A sample of activated sludge from the aeration tanks at Coleshill, after standing without aeration for some hours, was divided into two portions. One was reaerated continuously; the other remained unaerated in a stoppered bottle. During this time counts were made periodically of the numbers of attached and free-swimming *Vorticella*. The percentage numbers of telotrochs present at different times in the two samples (Figure 4) show that in the aerated sample the percentage of

telotrochs gradually fell until practically all the *Vorticella* were in the attached form. In the non-aerated sample, on the other hand, the numbers of telotrochs gradually increased. The experiment was repeated using returned activated sludge in poor condition and on this occasion the dissolved oxygen content was determined at the time of the counts. The results (Table II) show that the dissolved oxygen content was not raised significantly by aeration and although the percentage of telotrochs increased in the non-aerated sample and decreased in the aerated sample there was no correlation between these changes and the dissolved oxygen.

Discussion

The results of this work confirm the generally accepted view that the qualitative nature of the protozoan fauna of an activated sludge is indicative of the quality of the effluent and that a restricted fauna of peritrichous forms is associated with an effluent of good quality. The quantitative relationship established between the numbers of vorticellids and purity of the effluent

TABLE II.—Proportion of Free-Swimming *Vorticella* in Activated Sludge under Varying Conditions of Aeration

Sample	Vorticella			D.O. (p.p.m.)
	Stalked Forms (no.)[1]	Free-Swimming Forms		
		(no.)[1]	(%)[2]	
A. Return activated sludge	25	18	42	0.9
B. Aerated for 15 min.	33	4	11	—

Elapsed Time (hr.)	Aeration of B Continued				Aeration of B Stopped			
	Stalked Forms (no.)[1]	Free-Swimming Forms		D.O. (p.p.m.)	Stalked Forms (no.)[1]	Free-Swimming Forms		D.O (p.p.m.)
		(no.)[1]	(%)[2]			(no.)[1]	(%)[2]	
0.5	29	8	22	—	24	14	37	1.24
1.0	23	4	15	0.99	28	17	38	0.80
1.5	23	4	15	1.13	—	—	—	—
2.0	35	2	5	0.50[3]	57	2	4	0.67
2.5	40	1	2	1.00	39	6	13	0.92[4]
3.0	43	1	2	0.30	33	29	47	0.62
3.5	56	2	4	0.70	48	18	27	0.95
4.0	42	0	0	1.04	32	11	26	0.55
4.5	45	1	2	1.00	24	12	33	0.75
Aeration Stopped								
0.5[5]	50	0	0	0.8	—	—	—	—
1.0[5]	54	0	0	0.57	—	—	—	—
1.5[5]	45	2	4	1.80	—	—	—	—

[1] Number per unit volume.
[2] As percentage of total.
[3] Suspended solid interfered with determination.
[4] Air trapped in D.O. bottle.
[5] After aeration was stopped.

for the sludge at Huddersfield (5), although confirmed over a short period (Figure 1), did not hold throughout the longer period (Figure 2). At Huddersfield, the large amounts of industrial wastes are likely to restrict the ciliate fauna, whereas at Coleshill the domestic sewage encourages a varied protozoan fauna. While a simple relationship between a restricted peritrichous ciliate population and effluent quality might exist, as at Huddersfield, this might be masked in the Coleshill sludge by the competition between several species. Figure 2 shows that *Vorticella* spp. and *Opercularia* become successively dominant, and that only by considering the sum of the two is any correlation obtained with the effluent purity. Throughout the period, also, peaks of the two most common free-swimming ciliates (*Lionotus* and *Aspidisca*) succeeded one another and usually coincided with those of the total peritrichous ciliates. It seems reasonable to assume that similar conditions favored all these species and, because of interspecific competition, the sum total of all should be considered in looking for correlation with the quality of the effluent. In fact, Figure 2c shows that better correlation is obtained with the sum of these species than with the individual species.

Other ciliates were common on occasions during the period. These included the genera *Amphileptus*, *Euplotes*, *Oxytricha* and other hypotrichous ciliates, *Paramoecium*, and *Colpidium*; but in comparison with the numbers of the total ciliates their numbers were considered insignificant. *Paramoecium* and *Colpidium* appeared at times when the effluent was poor, but further observations are necessary to establish the significance of these and other ciliates as indicator organisms at Coleshill. Previous workers have grouped *Aspidisca* with the peritrichous ciliates as indicators of good conditions (1)(4). *Lionotus*, together with *Oxytricha* and *Stylonychia*, have been classified as an intermediate sludge type, and *Paramoecium* and *Colpidium* as organisms indicative of a poor sludge (4).

Figure 3 shows that, except for a period during the summer months, peaks in the ciliate population coincide with, or closely follow, peaks in the inverted B.O.D. curve, but there is no direct quantitative relationship between the sum of these ciliates and the quality of the effluent. For example, the quality of the effluent during the period November 1951 to June 1952, when the ciliate numbers were comparatively low, was better than in the period September to December 1952, when the ciliate numbers were high. This greater number of ciliates is only partly due to a proportional increase in free-swimming forms. As seen from Figure 2a, the peritrichous forms also increased. During the later period, however, a different species of *Vorticella* (probably *V. microstoma*) replaced a larger species (*V. campanula*), which was dominant in the earlier part when the effluent was better. The dominance of the different species of *Vorticella* in relation to the quality of the effluent is being investigated further.

Previous workers have interpreted the qualitative relationship between the protozoan fauna and quality of the effluent in terms of the efficiency of the activated sludge, implying that the fluctuations in the quality of the effluent are due to changes in the efficiency of the sludge, which in turn are reflected in the protozoan population (1)(2)(3). In activated sludge developed in the laboratory, there was shown to be an ecological succession of protozoa dominated first by flagellates and then by ciliates. This change in fauna corresponded to a reduction in the time needed for clarification from more than 24 hr. to less than 3 hr. It does not necessarily follow that the ciliates themselves were responsible for this change, for their presence could equally

well be accounted for by the sludge creating more suitable conditions for their growth. However, several workers have demonstrated the power of ciliates to effect flocculation of turbid liquors (for example, *Paramoecium caudatum* (3)). The mechanism by which it is carried out has been studied for *Balantiophorus minutus* by Watson (7) and for *Carchesium* by Sugden and Lloyd (8). Other workers go further and claim that the ciliates take a more direct role in the breakdown of organic matter (9)(2); Pillai and Subrahmanyan (10) go so far as to claim that the ciliate *Epistylis* is capable of effecting purification and that bacteria are only of secondary importance. Cutler and Bal (11) and Meiklejohn (12) have shown that the activity of certain bacteria is enhanced by the predatory activity of ciliates. On the other hand, Butterfield and Wattie (13) have shown that zoogleal bacteria alone are capable of purifying sewage.

There seems little doubt that these ciliates are capable of such activities, but the extent to which they are operative under plant conditions has not yet been determined. Jenkins (14) considered that flocculation, although important in purification, was not dependent upon protozoa. Barker (3) found no signs of increased purification corresponding to an increased protozoan population in the trickling filters at Knostrop (Leeds), and although there was such a correspondence at Bradford, it was not certain that the increased purification was due to the increased protozoan population. Reynoldson (5) also concluded that "any active part which *Vorticella* and other protozoa take in the purification of sewage remains to be determined."

The present work did not produce any evidence that purification was enhanced when the ciliate population was high. The correlation between the quality of the effluent and the ciliate population seems to be explained in terms of the effect of the effluent on the protozoan fauna, as the fluctuations in ciliate numbers follow the fluctuations in the B.O.D. of the effluent. This view is substantiated by considering the factors influencing the quality of the effluent. The larger fluctuations in effluent quality (Figure 3c) are mostly accounted for by similar fluctuations in sewage strength, apart from any variation in sludge efficiency. The sewage strength and the dissolved oxygen concentration are related to rainfall, although the dissolved oxygen is also affected by temperature and sludge concentration. Because fluctuations in effluent quality are for the most part explained in terms of these factors, apart from any variation in sludge efficiency, the fluctuations in the ciliate population may now be similarly explained. Thus (Figures 3b and 3c), when there was no correlation between the ciliate numbers and the B.O.D. of the effluent there was correlation between them and the B.O.D. of the sewage. It is deduced, therefore, that the ciliate population in the sludge is largely determined by the different conditions prevailing in the plant, including the aeration tanks, settlement tanks, and return sludge circuit, the extremes of which are fixed by the incoming sewage and outgoing effluent. Thus, the protozoan fauna indicates the quality of the sludge only to the extent that the quality of the effluent is affected by the condition of the sludge.

Rainfall might be responsible for flooding the natural habitats of these ciliates, thereby re-inoculating the activated sludge when surface water mixes with the incoming sewage. Reynoldson (15) has shown that in the natural habitat of a pond there was a significant positive correlation between the population of the peritrichous ciliate *Urceolaria mitra* and the rainfall. In relation to the lag of the ciliate curve behind the B.O.D. curve (Figure 2c) in the colder periods, it is of interest to

note that in the colder periods there was a similar lag of the peaks of the *Urcoelaria* population behind the rainfall peaks.

From a practical point of view, qualitative microscopical examination of the sludge is useful in assessing the general conditions of an activated sludge plant. Before a quantitative index can be applied in terms of ciliate populations, much work remains to be done. So far it is not possible to explain periodical increases in the population of different species, especially the free-swimming forms. Such increases are known throughout the animal kingdom, but in the case of the more rapidly reproducing protozoa they are likely to recur more frequently. A further difficulty is one of specific identification, as it may be that species within a genera react differently to varying conditions. There is also the problem of interference due to toxic discharges in the sewage; changes in the bacterial flora may also be of importance in determining the protozoan fauna. Also, the correlation that does exist is between the ciliate population and the B.O.D. of the settled effluent. At times, even though the settled effluent is of good quality, the final effluent from the plant contains a considerable amount of non-separated sludge (due to bulking conditions), and this appreciably increases the final B.O.D. This is not indicated by the protozoan fauna.

At first it was thought that the proportion of free-swimming forms of *Vorticella* might serve as an indication of the dissolved oxygen of the mixed liquor in the aeration tanks. Experiments showed, however, that although the change from attached to free-swimming forms is related to the degree of aeration, there was no correlation with the dissolved oxygen.

Summary

1. Intensive study over a short period showed that there was an inverse correlation between the numbers of peritrichous ciliates in the activated sludge and the B.O.D. of the effluent. This was not so for the free-swimming ciliates.

2. Observations for a period of more than one year showed that this correlation was closer when the sum of the peritrichous ciliates plus certain of the free-swimming forms was considered.

3. The correlation did not hold at all times throughout the longer period of observations; when it did not, there was a correlation between the ciliate population and the B.O.D. of the sewage. This period occurred when the temperature was above 15° C.

4. Large fluctuations in the quality of the effluent are accounted for by corresponding fluctuations in sewage strength, which in turn are related to rainfall. The dissolved oxygen in the aeration tanks is also related to rainfall and sewage strength, as well as to temperature.

5. It is considered that changes in these environmental factors affect both the ciliate population and the quality of the effluent.

6. There is no evidence from the present investigation to indicate that increased ciliate populations lead to improvements in the quality of the effluent.

7. It is concluded from this investigation that a relationship between protozoan numbers and sludge conditions or effluent quality cannot yet be expressed on a quantitative basis. Furthermore, the proportion of free-swimming to total vorticellids does not appear to be related to the dissolved oxygen concentration, although this proportion is in some way related to the degree of aeration.

Acknowledgments

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References

1a. Lockett, W. T., "Appendix to the Rivers Department Annual Report, Appendix to Manchester Council Minutes" (1927–8–9); also reported in:

1b. Ardern, E., and Lockett, W. T., "Laboratory Tests for Ascertaining the Condition of Activated Sludge." *Jour. Inst. Sew. Purif.*, 212 (1936).

2. Barritt, N. W., "The Ecology of Activated Sludge." *Ann. Appl. Biol.*, **27**, 151 (1940).

3. Barker, A. N., "The Ecology and Function of Protozoa in Sewage Purification." *Ann. Appl. Biol.*, **33**, 314 (1946).

4. Horasawa, I., "Biological Studies on Activated Sludge in the Purification of Sewage. II. Characteristics of Activated Sludge Biota and its Ecological Classification." *Jour. Water Works and Sew. Assn.* (Japan), No. 181, 8 (1949).

5. Reynoldson, T. B., "*Vorticella* as an Indicator Organism for Activated Sludge." *Nature* (London), **149**, 608 (1942).

6. Winsor, C. E., "The Operation of Coleshill Works 1938–1952." *Jour. Inst. Sew. Purif.*, (1953). In press.

7. Watson, J. M., "Mechanisms of Bacterial Flocculation Caused by Protozoa." *Nature* (London), **155**, 271 (1945).

8. Sugden, B., and Lloyd, L., "The Clearing of Turbid Waters by the Ciliate *Carchesium*. A Demonstration." *Jour. Inst. Sew. Purif.*, 16 (1950).

9. Viehl, K., "Investigations Concerning the Nature of Self-Purification and Artificial Biological Sewage Purification." *Z. Hyg. Infekt.*, **119**, 383 (1937).

10. Pillai, S. C., and Subrahmanyan, V., "The Role of Protozoa in Aerobic Purification of Sewage." *Nature* (London), **154**, 179 (1944).

11. Cutler, D. W., and Bal, D. V., "The Influence of Protozoa on the Process of Nitrogen Fixation by *Azotobacter chroococcum*." *Ann. Appl. Biol.*, **13**, 516 (1926).

12. Meiklejohn, J., "The Effect of *Colpidium* on Ammonia Production by Soil Bacteria." *Ann. Appl. Biol.*, **19**, 584 (1932).

13. Butterfield, C. T., and Wattie, E., "Effective Bacteria in Purification by Trickling Filters." *Sewage Works Jour.*, **13**, 4, 639 (July, 1941).

14. Jenkins, S. H., "The Role of Protozoa in the Activated Sludge Process." *Nature* (London), **150**, 607 (1942).

15. Reynoldson, T. B., "Natural Population Fluctuations of *Urceolaria mitra* Epizoic on Flatworms." *Jour. Anim. Ecol.*, **19**, 106 (1950).

MAKE YOUR HOTEL RESERVATIONS FOR THE FSIWA TWENTY-SIXTH ANNUAL MEETING

The Bayfront Park Auditorium at Miami, Florida, will be the headquarters for the Federation's Twenty-Sixth Annual Meeting, to be held October 13–16, 1953. An outstanding technical and social program is being planned for the four-day meeting.

Requests for room reservations should be addressed directly to the FSIWA Housing Committee, 320 N. Fifth St., Miami, Fla. (see page 1125 for details). It should be noted that the technical program will open on Tuesday morning, October 13, and will close at noon on Friday, October 16, but early arrivals may register on October 12.

WRITE NOW FOR YOUR RESERVATIONS!

Industrial Wastes

DISPOSAL OF FOOD PROCESSING WASTES BY SPRAY IRRIGATION *

By N. H. Sanborn

National Canners Association Research Laboratory, Washington, D. C.

Disposal of industrial wastes after a minimum of treatment in such a manner as to avoid stream pollution completely has long been the goal of those interested in waste disposal. Until recently, disposal into impounding lagoons or, less frequently, soil absorption from a ridge-and-furrow irrigation system or from absorption beds has most nearly approached this goal. The chief objection to the impounding of food processing wastes is the odor evolved during bacterial stabilization of the waste. Use of odor control agents is expensive and not always uniformly successful. Absorption by ridge-and-furrow irrigation or from absorption beds is limited to soils of relatively high water absorbing capacity. The development of spray irrigation has provided another method for the disposal of wastes from the canning, frozen food, and dairy industries under conditions which do not pollute streams or create odors. The method is capable of extension to certain other industrial wastes.

Development of Method

Disposal by spray irrigation is an adaptation from the well-known method of watering agricultural crops by portable sprinkling irrigation systems. In agriculture, supplemental crop irrigation may be obtained by pumping water through portable pipes to self-actuated sprinkler heads. Light-weight aluminum or galvanized piping equipped with quick-assembling pipe joints permits moving and assembling the pipe over areas to be irrigated. Using the same equipment, wastes may be applied as a rain to the surface of soil. In agricultural irrigation the objective is to supply the minimum water required to produce maximum crop production; in waste disposal the objective is to apply the maximum amount of waste water which can be absorbed without surface runoff or damage to the cover crop.

In 1947, the Hanover Canning Company, at Hanover, Pa., was faced with the problem of preventing any lagoon overflow from entering a small stream. The company had on hand portable agricultural equipment used for the watering of crops grown by the canning company. Faced with the disposal of the excess lagoon water it was a logical step to turn to spray irrigation. This was the first application of spray irrigation for the disposal of waste water (1). In 1950, spray irrigation was used for the disposal of all factory waste water from the frozen food and canning plant at Seabrook Farms in New Jersey (2) and from the Lakeside Packing Co. in Minnesota (3) (4). In 1951, a total of 22 plants in the canning and frozen foods industries were using spray irrigation for the disposal of factory wastes (5). Not previously reported are the two dairy plants described in this report; these plants used spray irrigation in 1951. All of the plants mentioned continued the use

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of spray irrigation in 1952. In addition, more than 20 more spray systems were installed at canning plants.

For waste disposal, a spray irrigation system is comprised of the following units:

1. The land on which to spray.
2. A vegetative cover crop to aid absorption and prevent erosion.
3. A mechanically-operated screening unit.
4. A surge tank or pit.
5. Auxiliary stationary screens.
6. A pump which develops the required sprinkler nozzle pressure.
7. A main line.
8. Lateral lines.
9. Self-actuated revolving sprinklers operating under 35- to 100-p.s.i. nozzle pressure.

Typical Plants

A brief description of the equipment in use and the method of operation serves to illustrate the application of spray irrigation for the disposal of food processing wastes.

Cannery Plant

The first plant is an average-size two-line cannery packing peas and corn. The equipment used at this plant is as follows:

1. Screening unit. An existing rotary screen was used.
2. Wet well. A 30-in. pipe, 100 ft. long, located underground, and holding approximately 3,600 gal., served as the wet well.
3. Pump. The pumping unit consisted of a 150-g.p.m. centrifugal pump powered by a 10-hp. motor operated by a tape float control.
4. Irrigation main line. A total of 2,100 ft. of 4-in. aluminum pipe in 30-ft. sections was used to pipe screened wastes from the plant to the irrigation field.
5. Sprinkler lateral lines. One lateral 1,200 ft. long and composed of 30-ft. sections of 4-in. aluminum pipe with 1-in. cast-iron pipe risers spaced 60 ft. apart was provided.
6. Sprinklers. Twenty sprinklers were used, each delivering 15 g.p.m. at 45-p.s.i. pressure.
7. Irrigation field. Irrigation was done on a farm field planted some six weeks prior to the pea pack with a grass mixture consisting of intermediate wheat, smooth brome, orchard, and alta fescue. The field was almost level. The soil consists of a thin layer of silt-loam underlain with shale and red clay.
8. Emergency lagoon. A lagoon used in prior years was available for emergency use.

Items 2 to 6, inclusive, cost $2,700, with installation charges of approximately $400. One man operated the spray irrigation system, tended the screening unit, and in spare time kept the factory yard in a tidy condition.

The grass mixture seeded to the irrigation field was suggested by a seed company as one that would stand considerable moisture and yield crops of hay. No evidence of damage from excessive moisture was observed, in spite of above-normal precipitation.

The single lateral served, in effect, as two laterals. Of the 20 sprinklers, 10 were used for irrigation during a normal operating day of approximately 14 hr. On the following day the first set of 10 sprinklers would be turned off and the second set turned on, thereby obtaining two days of irrigation before moving the entire lateral a distance of 60 ft. to a new setting. Waste was spray irrigated at a rate of 150 g.p.m.—10 sprinklers operating at 15 g.p.m. The pea pack started on July 1 and ended on August 1, during which time 104,788 standard No. 2 equivalent cases were packed. Fifteen acres were planted to the mixed grasses, but only half the acreage was required for waste disposal. Wastes from a corn pack of 89,240 cases, on a No. 2 basis, were subsequently disposed of on the same area.

An excellent illustration of the important part that a cover crop plays in the rate of absorption was observed at this plant. The grasses were sown (drilled in rows) about the first of May. During the latter part of July the grass hay crop was cut over a period of several days. Wastes applied at this time to the uncut area were absorbed at a rate which permitted sprinkling on the same area for the entire day. The cut area of the field exposed considerable bare ground between the planting rows and wastes were not absorbed as readily, only about one-half as much being absorbed as on uncut areas. On one area, which was cut following a rain, packing of the soil by cutting and hauling operations further reduced the rate of absorption to only about one-quarter of that obtained on uncut grass. These observations were confirmed at other plants.

On several occasions the pump intake screen became clogged, necessitating pulling the pump. During the short shut-down periods wastes were diverted to the emergency lagoon.

Although the operation of the spray irrigation disposal system was satisfactory, with no runoff, odors, or damage to the field or stand of grass, the following changes are to be effected prior to the next session:

1. The screening unit will be remodeled to insure complete removal of all screenable solids.

2. In addition to the present 15-acre field of grass, an additional field of 11 acres will be planted in alfalfa to provide a financial return from alfalfa cuttings. Cattle will be grazed on the grass field. To avoid applying waste to the relatively thin stand of cover crop which prevails immediately following the harvesting of a crop of alfalfa or hay, it is planned to make a first alfalfa cutting 10 days prior to the start of the canning season. Subsequent cuttings of alfalfa and hay will be made on portions of the fields and so timed that 10-day growing intervals will elapse between cutting and waste spraying.

Dairy Plant

The second plant to be described using spray irrigation is a dairy located in Southern New Jersey. In this area the winters are mild enough so that wastes may be sprayed nearly every day. On occasions when spraying is not possible, wastes are retained in the surge pit.

This dairy receives 80,000 to 90,000 lb. of milk per day, which is processed into pasteurized milk, chocolate milk, cottage cheese, and ice cream. Approximately 75,000 g.p.d. of waste water is produced. Domestic wastes from 135 employees and wastes from a dairy barn for 130 cows are included. Condenser cooling water is by-passed. The disposal system at this dairy includes the following:

1. Septic tanks. Wastes from existing septic tanks for domestic sewage, factory wastes, and dairy barn wastes are combined and flow to a newly constructed septic tank that provides approximately 45-min. detention for a design flow of 250 to 300 g.p.m.

2. Surge sump. Wastes from the final septic tank discharge into an earthen basin holding 5 to 6 days flow.

3. Pump. The pumping unit consists of a 15-hp. centrifugal pump with a capacity of 200 g.p.m. at 80-p.s.i. pressure.

4. Irrigation main line. A total of 2,760 ft. of 5-in. aluminum pipe delivers wastes to the irrigation fields.

5. Sprinkler lateral lines. A total of 2,240 ft. of 4-in. aluminum pipe is available for lateral lines.

6. Sprinklers. Fifty-nine ¾-in. sprinklers each deliver 10.5 g.p.m. at 45-p.s.i. nozzle pressure. Sprinklers are located at 40-ft. intervals on the laterals.

7. Irrigation fields. An entire farm is available for irrigation, but only a maximum of 45 acres of hay fields are

TABLE I.—Equipment, Operation, and Cost Data for Typical Spray Irrigation Systems

	Plant				
	A	B	C	D	E
Main line:					
Length (ft.)	1,820	4,800	6,100[1]	2,800[2]	2,400
Size (in.)	6	6	8 and 6	6 and 4	4
Laterals:					
Length (ft.)	450	640[3]	780[4]	300	600
Size (in.)	4	5 and 4	5 and 4	4	4
Number	2	2	3	4	2
On per spraying	1	1	2	2	1
Sprinklers:					
Flow (g.p.m.)	18	20	20	9	20
Spacing (ft.)	40	40	40	60	60
Moves (ft.)	100	80	100	none	90
On at one time	11	16	38	24	10
Waste application:					
Total (g.p.m.)	198	320	760	216	200
In./hr.	0.44	0.6	0.5	0.15	0.44
Pump, type	Gasoline	Gasoline	Gasoline	Electric	Electric
Acreage:					
Available	15	67	80	24	20
Used	5	30	80	8	20
Cases packed	119,000	193,000	409,000	251,000	149,000
Cost[5]	$3,400	$8,000	$14,300	$5,000	$4,500

[1] 5,400 ft. of 8 in. and 700 ft. of 6 in.
[2] 1,800 ft. of 6 in. and 1,000 ft. of 4 in.
[3] 160 ft. of 5 in. and 480 ft. of 4 in.
[4] 390 ft. of 5 in. and 390 ft. of 4 in.
[5] Spray irrigation equipment only—pumps, motors, pipe lines with fixtures, and spray nozzles.

spray irrigated. The soil is a light sandy loam.

Items 3 to 6, inclusive, together with the auxiliary tees, elbows, end plugs, valves, etc., cost $5,817 in 1951. The total cost including items 1 and 2 and installation was approximately $15,000. The system was designed to handle 144,000 g.p.d. at the rate of 200 g.p.m. for a 12-hr. day.

Analyses of the wastes show the following range:

pH	7.12 to 7.6
B.O.D.	250 to 355 p.p.m.
Total solids	516 to 650 p.p.m.
Vol. solids	270 to 470 p.p.m.
Ash	158 to 246 p.p.m.

The system at this dairy provides for great flexibility of operation by virtue of the 5- to 6-day surge sump, the availability of excess laterals, and more hay and pasture fields than can be irrigated from the existing supply of waste water. Pump capacity limits operation to a maximum of 18 sprinklers at any one time. Normally, wastes are sprayed every other day. Laterals are changed or sprinklers turned on or off so that no more waste is applied than will be beneficial to the hay crop.

Dairy cows are pastured in fields irrigated with waste. The New Jersey State Board of Health has given approval to this procedure providing an interval of 10 days elapses between the time spraying is discontinued and milk cows are turned into pasture.

Small Dairy Plant

The disposal of wastes from another dairy in Southern New Jersey is essentially the same. This dairy processes 28,000 lb. of milk per day. Wastes from dairy operations, together with domestic sewage from 30 persons and

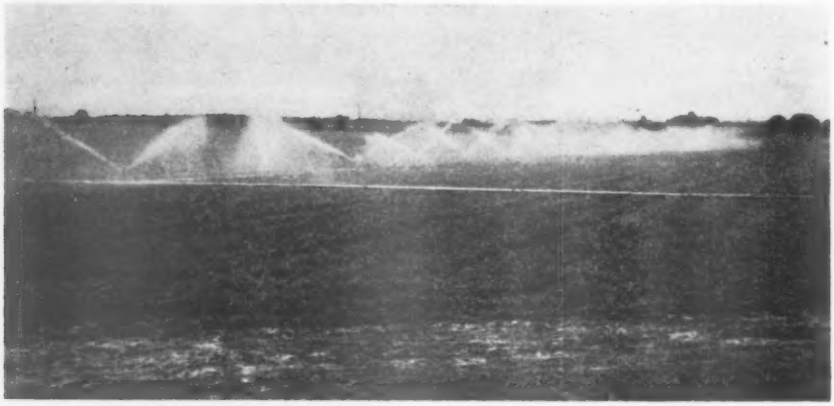

FIGURE 1.—Disposal of pea cannery waste by spray irrigation.

from barns for 100 cows, average 80,000 g.p.d. with a maximum of 90,000 g.p.d. After passing through a septic tank, the combined wastes enter a surge pit 40 ft. by 15 ft. by 12 ft. A centrifugal pump powered by a 25-hp. motor equipped with a starter control and a Mercoid pressure switch deliver the waste through 960 ft. of 5-in. aluminum pipe to a single 1,200-ft. 4-in. aluminum lateral equipped with 30 ¾-in. sprinklers spaced 40 ft. apart. Pump capacity is 300 g.p.m. at 100-p.s.i. pressure. The pump motor assembly and spray equipment cost $2,925 in 1950. The entire installation, exclusive of land, cost $5,200.

Wastes are sprayed onto 100 acres of pasture composed of orchard grass and ledino clover. The soil consists of a

FIGURE 2.—Spray irrigation of cannery waste on pasture.

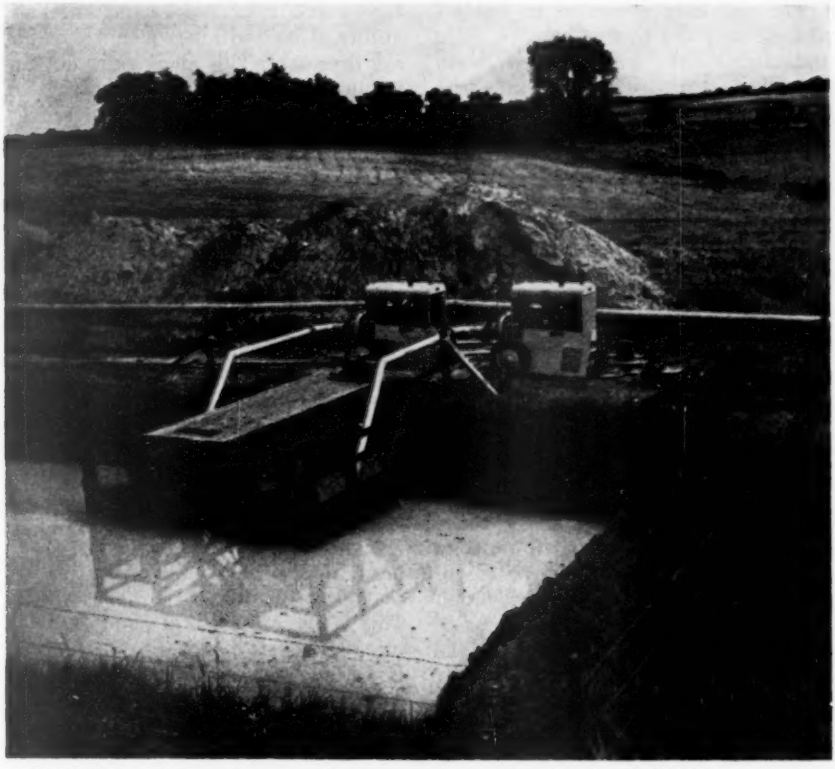

FIGURE 3.—Pump surge pit with corn cannery waste, showing dual irrigation pumps with suction pipes surrounded by auxiliary screens.

10- to 12-in. layer of clay loam over clay and gravel. The lateral is moved once a day, with 7 moves on each of 9 fields. Dairy cows are pastured on spray irrigated fields with observance of the 10-day interval between spraying and pasturing. No difficulty has been experienced with winter spraying.

Additional Plant Data

The equipment, cost data, and some operational features for five additional spray irrigation systems in use at canning plants are summarized in Table I.

The high rate of absorption at Plant A was due to the sandy nature of the soil and at Plant D to spraying in woods. At the latter plant, two laterals were set up in permanent locations and operated on alternate days. It is interesting to note that only from one-third to one-half of the total available acreage was required to absorb the applied wastes except in the case of Plants C and E. At Plant C all the available acreage was used because the entire area had been planted to a new cover crop and also because an accumulation of lagooned pea waste was being disposed of together with the currently produced corn waste. At Plant E the waste water was sprayed over the entire available acreage to secure the maximum benefit of irrigation for the growth of the hay crops. The packing data are for a single pack of either peas or corn, expressed as cases of No. 2 cans. Except at one plant, the same fields received spray applications from a second pack.

The cost data presented in Table I include only the pumps, motors, main and lateral lines, with their necessary valve and other pipe fittings, and sprinkler nozzles peculiar to spray operation. The systems, of course, were set up to handle the packing of that product which produced the maximum quantity of waste. The same facilities were used during the packing of at least one other product. Typical spray irrigation disposal systems for cannery wastes are shown in Figures 1, 2, and 3.

It would be beyond the scope of this paper to prepare a complete cost analysis of waste disposal by spray irrigation at a number of different plants because of several reasons, among which may be mentioned: (a) the great differences in utilization of existing equipment, such as screening units, surge sumps, pipe lines, etc.; (b) differences in land values; (c) great variations in the distance of plants from irrigation areas; (d) the necessity in some cases of purchasing rights-of-way; (e) the extra cost sometimes involved in the crossing of railroads and roads; (f) the necessity in some cases of laying all or part of the main pipe line underground; and (g) differences in the rate of soil absorption, or the rate of application, or the use to which the irrigated land is put (crop production, cattle grazing, or purely as a waste disposal area), all of which influence the acreage required for the disposal of the same volume of waste.

Problems and Limitations

The foregoing examples illustrate the application of spray irrigation for the disposal of food processing wastes. In principal, the method appears quite simple. Observations made at nearly all of the spray irrigation systems in operation during the past two years confirmed this, but they also revealed certain problems and limitations.

Land Availability

Because disposal depends upon soil absorption, it is obvious that the factor of first consideration is the availability of land within economical pumping distance. This alone rules out the application of spray irrigation for some plants; fortunately, however, most food processing plants are located in rural areas where land is available. It may be more economical to apply spray irrigation at a site a mile or so distant than to treat by certain methods at the plant or to pay the service charges asked by some municipalities for acceptance of strong wastes into the sewer system. At one plant, for example, it was found that spray irrigation was the best solution, even though it was necessary to lay a 10-in. asbestos-cement pipe and pump a distance of more than 3.5 mi. to the disposal site.

Cover Crop

Mention was made previously of the importance of a cover crop in relation to the absorption of sprayed wastes. This is one of the vital points for the successful operation of spray irrigation. It was thought at first that spray irrigation would be applicable only in areas where the soils had unusually good water absorbing characteristics. Experience has shown the method to be applicable in regions of rather poor soil characteristics, providing an adequate cover crop is present.

Spraying onto bare or essentially bare soil will not achieve the degree of absorption without runoff necessary for the disposal of relatively large quantities of waste on restricted acreage. This has been the experience of all who have tried to utilize bare or poorly covered ground, even when the soil was quite sandy. The impact of drops of water from natural or artificial rain is great enough to fracture soil granules. The resulting fines are classified, with the finest particles on the surface, partially sealing off the entry of water into the lower soil.

An inert ground cover, such as straw, absorbs the impact of falling drops of water to prevent the conditions just described. So, too, does growing vege-

tation. In addition, a growing cover crop increases infiltration by virtue of its root system and helps dispose of absorbed ground moisture by transpiration.

The choice of cover crop to be used depends on geographical location, type of soil, and the particular use to which the irrigated land is put. Early attempts to utilize waste water for the watering of crops such as peas, beans, and small grains, were not entirely satisfactory for the simple reason that the quantity of water to be disposed of exceeded the tolerance of the crops. Damage from over-watering was the consequence.

Waste Disposal vs. *Profit*

Disposal of wastes by spray irrigation should be regarded primarily as a method of waste disposal. In times of drought some or all of the waste may be diverted with good advantage from disposal areas to the watering of crops.

This is not to imply that wastes need be spray irrigated without regard to some financial return. On the basis of present experience it appears that a satisfactory procedure is to have available sufficient acreage planted to alfalfa or hay, which can be harvested, or as pasture lands, on which cattle can be grazed. On a purely observational basis, unsupported by quantitative data, it appears that the dense, low-growing grasses of good pastures are most satisfactory.

Rates of Application

With fields having a good cover crop and lying fairly level, it is common practice to apply from 3 to 4 in. of waste at a rate of 0.4 to 0.6 in. per hour. When float-controlled electric pumps are used in conjunction with small surge sumps, waste application is intermittent. The total elapsed time may be long enough so that a lateral need not be moved more often than twice a day. Under favorable conditions only one move per day of 10 to 15 hr. of operation is not uncommon. An area sprayed at the rate mentioned may be resprayed after about six days.

One good method of operation calls for the use of two laterals. Wastes are sprayed alternatively for 1-hr. periods. The "down" periods permit complete absorption of surface water. Transpiration and evaporation are at a maximum. This operational procedure requires the continued presence of a man at the irrigation site. Other procedures will suggest themselves according to the availability of manpower; the quantity of waste requiring disposal; the size, length, and number of laterals; and the size and shape of the disposal area.

Wastes are being sprayed to good advantage in wooded areas. Absorption rates are high. It is not feasible to move laterals in woods, consequently they remain in position. At some installations where giant-size sprinklers each covering a circular acre are used, the sprinklers themselves are moved along the laterals. At the smaller installations each lateral is provided with a control valve. The ability of trees to withstand without injury the quantity of water now being sprayed upon them remains to be established.

It is not known at present to what extent mineral nutrients may be leached out by the application of abnormally high quantities of water. Food processing wastes will supply some nutrients. Pea waste, for example, has been found to contain an average of 46 p.p.m. total organic nitrogen and 9 p.p.m. ammonia nitrogen. It has a total phosphorus content of about 8 p.p.m., of which 5 p.p.m. are in the form of soluble phosphate. Corn waste has an average of around 54 p.p.m. total organic nitrogen and 2 p.p.m. ammonia nitrogen. Total phosphorus averages 11 p.p.m., of which 5 p.p.m. are present as soluble phosphates. Studies involving soil analysis and crop and pasture yields over a period of several years are needed to answer questions raised by the intensive spraying of food processing wastes.

Pretreatment

Screening has always been considered an indispensable preliminary treatment, regardless of subsequent treatments or methods of disposal. Disposal by spray irrigation is no exception; in fact, failure to screen properly has led to the chief operational difficulty encountered. All too many screening units permit some spillage of solids back into the flow of screened waste. This may not lead, ordinarily, to trouble with other systems, but with spray irrigation all of the waste must pass through the relatively small orifices of the sprinklers. A few individual pieces of solid material large enough to plug the sprinklers will play havoc in the operation of the system. Stringy material, such as beet roots or pieces of pea vines, will bind in pumps, reducing their capacity to a point where they must be taken out of operation and dismantled.

Screening through a 10-mesh screen should provide ample screening. Some State Boards of Health specify screening through finer mesh, but these requirements were established before the advent of spray irrigation. For various reasons it is easier to obtain a good job of screening through a 10-mesh screen than through, say, a 40- or even a 20-mesh screen. There is no advantage in the removal of very fine solid material in so far as spray irrigation is concerned. Repeated observations have been made in fields sprayed with beet wastes containing large quantities of finely divided solids. A negligible quantity of fine material may adhere to the vegetation, but there is no evidence of any accumulation of solids in a thick vegetative cover, although on bare spots a mat may build up.

Further Screening

It is inevitable that at times some solid material will by-pass the screening unit or trash may be thrown or blown into the screen sump or the surge sump. These contingencies are taken care of by installing a stationary screen in the surge sump around the suction pipe or hose. The size of the screen openings should approximate the diameter of the smaller or secondary nozzle opening. At some installations the smaller nozzle diameter is $\frac{5}{32}$ in. The present trend is towards a $\frac{1}{4}$-in. nozzle opening.

Sprinkler Selection

A wide selection of sprinklers is available. For the spraying of wastes in fields or pastures, sprinklers having a delivery of 15 to 25 g.p.m. are used. These sprinklers spray over a diameter of 120 to 140 ft. For spraying large volumes in wooded areas, sprinklers covering a circular area of approximately one acre are being used. The sprinklers delivering only 9 g.p.m. at Plant D (Table I) have given good performance in the handling of a smaller volume of waste at permanent stations in a wooded area.

Surge Sump

Experience is being gained concerning the optimum size of the surge sump. Food processing wastes rapidly undergo decomposition with the production of odors. Since odors are volatile, it is obvious that spraying will release and create or accentuate an odor problem. The detention period in the pump surge sump should be held to a minimum, therefore, so that the waste may be sprayed in a fresh condition. A concrete sump holding some 15 to 30 min. peak factory flow can be used in conjunction with a float-operated pump. Some irrigation systems employ gasoline- or diesel-powered pumps, which must be operated manually. For these units the surge sump must provide a substantial volume of waste to maintain operation over a reasonable period of time, thus obviating the necessity of frequent starting and stopping. In situations where the irrigation areas are not too close to the plant, homes,

stores, or highways, earthen sumps holding about one day's waste production are in use. A large sump has the advantage of providing some emergency storage capacity.

Pipe and Fittings

The self-draining feature of the quick-coupling connections on pipe for laterals which need to be moved is essential. On main distribution lines, however, tight connections must be maintained at all times. Several varieties of leak-proof couplings are available.

General

Laterals should not be set up so close to highways or adjacent property that spray can be blown onto them.

Unsuccessful attempts have been made to include the very potent pea stack seepage along with factory wastes. Burning of crops or the leaves of trees has invariably occurred.

Any form of disposal of waste onto land involves a calculated risk of pollution of wells or other underground water. The record of spray irrigation in this respect has been entirely satisfactory, with but a single exception involving a stratum of creviced limestone close to the surface. Information from soil borings and consultations with state sanitary engineers, state geologists, and state agricultural engineers provides the basis for selecting an area with little likelihood of polluting underground water, and also provides an appraisal of the potential capacity of soils in different areas to absorb water.

A spray irrigation system for the disposal of wastes involves a number of features familiar to the engineers specializing in the manufacture and installation of agricultural spray systems. They should be consulted. For example, a factor in maximum rate of absorption is uniformity of spray distribution. This is dependent upon maintaining the correct pressure at the sprinkler nozzles throughout the entire length of the sprinkler lateral. The solution of this problem depends upon the number and length of laterals, the size or sizes of pipe in the lateral, the size and number of sprinklers, friction losses, and land contours.

An economic problem is involved in the size of the laterals. Spray laterals of great length of large size pipe require several men and a truck for moving. Under wet field conditions cases are known where trucks have bogged down so that tractors had to be used, with the result that moving was delayed and damage was done to the cover crop. The use of several relatively short 4-in., or combination 4- and 5-in., aluminum laterals appears to be more practical.

As with other methods of disposal, certain limitations operate to prevent application of spray irrigation in particular cases. Spray irrigation is adapted primarily to disposal during non-freezing seasons, but recently it has been combined with winter lagoon storage for year-round disposal in cold climates. This development is being followed with interest. Other problems remain for further study, but the concensus of those familiar with the system is that spray irrigation as a method of disposal for canning, frozen food, and dairy wastes has met with success.

References

1. Siebert, C. L., and Allison, C., "Some Rights and Wrongs of Cannery Waste Treatment." *Water and Sew. Works*, **95**, 227 (1948).
2. Thornthwaite, C. W., "Agricultural Climatology at Seabrook Farms." *Weatherwise*, **4**, 27 (Apr., 1951).
3. Drake, J. A., and Bieri, F. K., "Disposal of Liquid Wastes by the Irrigation Method at Vegetable Canning Plants in Minnesota." Proc. 6th Ind. Waste Conf., Purdue Univ. (1951).
4. Nelson, L. W., "Cannery Wastes Disposal by Spray Irrigation." *Wastes Eng.*, **23**, 398 (1952).
5. Sanborn, N. H., "Spray Irrigation as a Means of Cannery Waste Disposal." *Canning Trade*, **74**, 33, 17 (Mar. 3, 1952).

SURFACE AND UNDERGROUND DISPOSAL OF CHEMICAL WASTES AT VICTORIA, TEXAS*

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Early in 1951 the du Pont Company started operations at its new chemical plant on the banks of the Guadalupe River, a few miles south of Victoria, Tex. This plant makes adiponitrile, an organic intermediate for nylon, and, like other industrial plants, produces a number of wastes which must be disposed of. Many of the wastes can and are being handled by established disposal methods. On the other hand, some wastes presented special problems so that new methods had to be devised to insure adequate disposal. The primary consideration in every case has been to avoid contamination of the Guadalupe River, of the fresh ground water, and of the atmosphere. This program was undertaken with the approval and encouragement of the Texas state authorities, who have been very helpful.

A preliminary discussion of the methods chosen to dispose of the various waste streams at Victoria has been presented by de Ropp (1). It is the purpose of the present paper to review these methods and to discuss some of the experiences and results obtained during the two years that the plant has been in operation.

Company Policy

In this plant the stringent waste disposal policy of the company is reflected to a high degree. According to this policy, development of a new process is not considered complete and new plant construction cannot be authorized until adequate waste treatment facilities have been included in the design.

In keeping with this policy, du Pont, at Victoria, has taken every precaution to keep the Guadalupe River clean. Downstream are rice growing, shrimping, and fishing industries that are vital to the welfare of many residents, and du Pont is obligated to avoid river contamination. The normal flow in the Guadalupe River is in the neighborhood of 300 to 400 cu. ft. per sec. This volume is adequate for cooling water requirements, but is not adequate for assimilating any large amount of waste.

Du Pont has so far spent about $1,600,000 on waste treatment facilities at Victoria to protect the rights of its neighbors and to be a good neighbor itself. Of this amount, $470,000 was spent in a large-scale experiment in subsurface disposal of chemical plant wastes through a deep well. In subsurface disposal the company took a financial risk beyond the initial cost, as there is no certainty at this time that the deep well will perform as expected and an alternative means may yet have to be found for some wastes. In the meantime, these wastes are being impounded in a diked basin.

Unique Features of Disposal System

The waste disposal system at Victoria involves three features, which are unique for a large chemical plant, as follows:

1. Concentrated aqueous wastes will be disposed of by injecting them into subterranean sands through a deep well.

* Presented at 1953 Texas Water, Sewage, and Industrial Wastes Short School; College Station, Tex.; March 8–12, 1953.

2. Solar evaporation is employed to dispose of a number of dilute aqueous waste streams.

3. Biological surveys are made of the Guadalupe River above and below the plant site, and of San Antonio Bay at the mouth of the river. These surveys provide a base for the biological condition of the river and bay so that any changes can be detected readily.

Types of Wastes

The wastes produced at Victoria fall into seven types, each of which requires a particular method of disposal. The major types are as follows:

1. Dilute aqueous solutions.
2. Concentrated aqueous solutions.
3. Cooling and storm water.
4. Organic liquids.
5. Waste gases.
6. Organic solids and trash.
7. Sanitary wastes.

Dilute Aqueous Solutions

There are a number of dilute wastes, consisting of purged process water, steam jet condensate, floor washings from manufacturing buildings and tank farms, and sink drainings from laboratories. The combined wastes total about 60,000 lb. per hour, most of which is water with a small amount of organic oils and some salt. Tests during development indicated that this waste would not be highly objectionable. Because of the possibility of pollution, however, this waste stream is disposed of by solar evaporation.

Both climatic conditions and the low permeability of the subsoil at the Victoria site are favorable for solar evaporation. Long-term analyses of rainfall and evaporation rates in the locality indicate that a net gain in evaporation of about 16 in. per year over and above rainfall should be obtained. Test holes drilled in the basin area before the plant was built indicated a continuous layer of impervious clay. Physical and chemical tests of this soil showed that no seepage would occur from the basin into the fresh-water strata. To verify that the fresh ground water is not being contaminated by seepage, samples of ground water from a number of test wells surrounding the basin are analyzed periodically. To date all the water samples have shown absence of contamination.

The evaporation is accomplished by impounding the dilute wastes in a 64-acre earthen basin with 5-ft. dikes. The incoming stream is first run into an oil separation area. Here, any oil is removed by decantation and the water flows into the main portion of the basin. It is important that the oils be removed from the water, as they greatly retard the evaporation rate.

The present basin was intentionally underdesigned to permit observation of this waste disposal method without committing more ground area than necessary for impounding purposes. As was expected, the water level has risen slowly during the past two years, at a rate of a little over 1 ft. per year. Aside from insufficient area in the existing basin, the solar evaporation method has appeared to be practical to date. The next step obviously would seem to be expansion of the impounding area. Before committing more new area, however, other methods, such as spray evaporation in an incinerator, submerged combustion, and subsurface disposal, are being considered.

Concentrated Aqueous Solutions

One of the purged process flows is a brine amounting to about 80,000 lb. per hour. This brine is an aqueous solution containing about 18 per cent sodium chloride, along with traces of metallic salts and organic compounds. The problem of disposing of this stream is a difficult one, for the high salt concentration makes solar evaporation or submerged combustion unattractive. Therefore, a system of underground disposal was devised.

Although little precedent is available for the subsurface disposal of chemical plant wastes, a close analogy can be found in the established practice of salt-water injection in oil field operations. Unlike oil field brines, however, the Victoria brine is a man-made waste which is foreign to the underground environment.

The waste brine is to be disposed of by injecting it into underground sands through a 4,800-ft. deep well. Prior to injection the brine must be treated to prevent the possible formation of precipitates, which would plug the well sands and shorten the life of the well. The treated brine must be free of suspended solids, and it must be stable, sterile, and unreactive with the natural brine and underground sand in the well; these are quality standards established from oil field experience in brine disposal.

The problem of making brine that is acceptable for underground injection turned out to be more difficult than originally visualized. As a result, start-up of the deep well was delayed. Although there were a few shortcomings in the original brine treatment method, much of the difficulty was caused by a widely varying composition of the brine feed to the treatment unit. The manufacturing step producing the brine had been going through an extended period of growing pains, and this was reflected in brine treatment. However, the difficulties have been resolved to the extent that treated brine of consistently good quality is being produced at present. The well is to be started up in the near future.

Up to now the waste brine streams, both treated and untreated, have been impounded in a 60-acre diked basin. This is adjacent to the solar evaporation basin previously described. After the well has been placed in operation, the impounding basin will be used for brine holdup in the event of a breakdown of the treatment plant or well. When the well is operating successfully, this additional basin area will be available for impounding dilute aqueous wastes for solar evaporation.

To evaluate the effectiveness of brine treatment, an arbitrary standard was set up which specifies that to be acceptable the treated brine must remain free of floc formation while standing for at least 24 hr. at 60° C. (the approximate temperature at 4,000 to 5,000 ft. below the surface). This stability test applies also to mixtures of treated brine and underground brine from the well. Floc in treated brine has usually been the result of either incomplete metals removal or a high concentration of organic materials, or both. The upper limit of metals concentration to give brine of consistently acceptable stability was found to be about 20 p.p.m. The organics content is controlled in the manufacturing step producing the brine, and not in the brine treatment unit. Floc is formed when the organics undergo partial degradation.

Another important criterion of effective treatment is that the brine can be passed through core samples from the well without affecting their permeability. The fineness of the well sand indicated the necessity for producing brine which is stable and free of suspended solids. The screen analysis of a typical sand sample showed that essentially 100 per cent passed through a 100-mesh screen and 20 per cent through a 200-mesh screen. In developing a suitable brine treatment process at Victoria, two separate methods were tried. Except for minor modifications, the same plant equipment was used for each method.

In the original treatment method, the waste brine was aerated to cool it and to oxidize the dissolved metals. Caustic was added to precipitate the metals as the hydroxides, with ferric chloride added as a coagulant. The pH after caustic addition was 10 to 11. The bulk of the precipitate was separated from the brine in a settling basin and

drawn off as a sludge. The remaining solids were removed in pressure filters packed with anthracite coal particles. Following filtration, the brine was acidified to decompose carbonates. The neutralized brine was then sparged with inert gas to remove oxygen and carbon dioxide. The final two steps of the treatment were chlorination to prevent algae and bacterial growths, and polish filtration.

This method gave treated brine of poor stability, mainly because of inadequate metals removal. Subsequent investigation showed that some of the metals were solubilized by the presence of a small amount of ammonia. It was also found that this ammonia interference could be minimized at pH values above 11.5. This modification of the original method using a higher pH (11.5 to 12) in the precipitation step was satisfactorily demonstrated in the plant equipment. The caustic requirement was considerably higher than in the original method, but good quality brine was produced.

A second treatment method was later developed in which sodium sulfide instead of caustic is used to precipitate the metals. This method is currently being used in the plant and is giving brine of satisfactory quality. To insure good control, the sodium sulfide (aqueous solution) is added in two steps. The bulk of the metals is removed in the first step, followed by clean-up in the second step. There are several advantages of the sulfide precipitation method over the high pH method, as follows:

1. Little or no caustic is required.
2. No coagulant is required.
3. The sulfide precipitate has better settling characteristics than the hydroxide precipitate.
4. No neutralization step is required.

In other words, the process is simpler and cheaper.

At present the disposal well is equipped as follows:

1. A 10¾-in. steel casing has been cemented in at the 2,448-ft. level. This casing is lined with Tube-Kote, a baked-on phenolic resin, to protect it against corrosion.
2. A 7-in. inner casing, also steel protected with Tube-Kote, extends from the surface to the 4,822-ft. level. It is cemented in from the 1,987-ft. level to the bottom.
3. A casing pressurizing system with automatic controls has been provided.

In completing the well, a production string of 3½-in. o.d. Ampco metal tubing, along with a packer and safety joint, is being installed. The Ampco tubing is also protected with Tube-Kote. The bottom 100 ft. of casing is being perforated. There is at least 500 ft. of permeable unconsolidated sands that appear suitable to receive the wastes.

In the event that subsurface disposal of the waste proves to be impractical, some other means of disposal, such as spray drying or submerged combustion, will be installed.

Cooling and Storm Water

Cooling-water contamination is prevented by operating all coolers and condensers with a higher pressure on the water side than on the process side. In addition, continuous analyzers with alarm hook-ups are provided for the detection of unusually objectionable materials. Although special precautions are being taken to prevent contamination, two large retention reservoirs are provided for the outlet water. These alternately fill and discharge, permitting a check to be made of water quality before discharge to the river. These so-called "passport ponds" hold 10 m.g. each and operate on an 8- to 16-hr. cycle. Should the impounded waters be found contaminated, they would be pumped to the 64-acre solar

evaporation basin. To date this has not been necessary.

Organic Liquids

Organic liquid wastes, amounting to about 3,000 lb. per hour, consist of hydrocarbons, both low-and high-boiling degradation products, and tars. These wastes are conveyed in corrosion-resistant tank wagons or, in some cases, by pipeline to a steel-encased, refractory-lined incinerator equipped with atomizing burners. The products of combustion, principally carbon dioxide and water vapor, are discharged from a 175-ft. brick-lined stack. The stack height has been calculated to disperse the gaseous products adequately. The performance of these facilities has been satisfactory to date.

Periodic checks are made on air samples taken down-wind from the incinerator stack to be certain that adequate dispersion is being obtained of the products of combustion released to the atmosphere. As a further precautionary measure, an outside expert in plant pathology made, at the du Pont Company's request, a survey of vegetation in the surrounding area during the past year. The results of this survey indicated no damage which could be attributed to discharged material from the incinerator stack. Additional surveys of this type will be made periodically in the future.

Waste Gases

Combustible waste gases, consisting largely of hydrocarbons and carbon monoxide, are burned under the powerhouse boilers, the combustion products being discharged from a 100-ft. stack. Excess gas and gas of variable composition is burned in the incinerator or flared through an emergency vent stack.

Organic Solids and Trash

A burning pit is provided for plant trash and solid process waste that cannot be handled in the liquid waste incinerator. These wastes average about 40 to 50 cu. yd. per week, and are collected and hauled to the burning pit in special dumping units.

Sanitary Wastes

Sanitary wastes are treated in an Imhoff tank. The sludge is dried on open beds and the effluent is retained in a lagoon for secondary treatment. The system was designed for an ultimate capacity well above the number of people working at the plant.

River and Bay Surveys

With the inception of the Victoria plant, the du Pont Company adopted a comparatively new approach in appraising the biological health conditions in streams. This is the application of a biological, or so-called "biodynamic" survey, which determines the type and number of different organisms present in a stream. Such a survey gives more basic information on the health of a river than do data obtained from such tests as B.O.D. and chemical analyses. By comparing the biodynamic data with similar data made on healthy streams having the same general characteristics, it is possible to classify the surveyed stream under such standards as healthy, semi-healthy, polluted, or very polluted.

To establish the condition of the Guadalupe River and San Antonio Bay before and after the plant start-up, the Academy of Natural Sciences of Philadelphia was engaged to undertake the biodynamic surveys. The Texas state authorities granted permission and were very helpful in planning and carrying out this program. Test stations were set up on the river near Seguin, and at several points above and below the plant site. To date three river surveys have been made. The first two surveys were made before the plant start-up and were one year apart; the third survey was completed in the summer of 1952, after the plant had been in operation for 1½ years. In every case, the river was found to be

healthy, with a normal biodynamic cycle functioning. Future river surveys will be made from time to time to insure that healthy conditions prevail in the river.

In addition to the Guadalupe River surveys, the Academy has been conducting surveys of the shrimp and oyster populations in San Antonio Bay at the mouth of the river. Because of the bay's importance to the local economy, and the necessity of establishing normal variations, these bay surveys are made each six months. To date, seven bay surveys have been completed, three before plant start-up and four after. Although there have been variations in the survey results from time to time, these are attributed to climatic and other local factors, and not to some agency entering the head of the bay such as pollution in the Guadalupe River.

Summary

In summary, the waste disposal facilities at Victoria have given satisfactory performance during the past two years. Experience with the various correction methods employed, including some new methods, has been beneficial. At the same time, there has been a successful effort to keep the atmosphere, the river, and the ground water clean. Although the outstanding highlight of the waste disposal program, the subsurface injection well, is yet to be proven, there is every indication that the well will work satisfactorily. If the well functions as expected, a significant milestone will have been passed in the ever-advancing science of waste disposal.

Reference

1. de Ropp, H. W., "Chemical Waste Disposal at Victoria, Texas, Plant of the Du Pont Company." THIS JOURNAL, **23**, 2, 194 (Feb., 1951).

CITIES CONDUCT IN-SERVICE TRAINING PROGRAMS

A variety of sources for aid and information are available to cities planning to establish in-service training programs.

An article in a recent issue of *Public Management*, monthly publication of the International City Managers' Association, points out that since January, 1951, about one-fifth of council-manager cities in the United States have conducted in-service training programs and a number of progressive pilot programs exist which could be the nucleus for healthy growth in the in-service training activities of other interested cities. The movement may be further implemented by federal subsidies for vocational education, state financial aid, and specialized courses conducted by state education agencies. In addition, local schools and colleges offer training opportunities, and training materials and advice can be obtained from a number of other public administration organizations.

A number of fields were covered by the 175 cities who have conducted training programs since January, 1951. They included employee safety or accident prevention training in 57 per cent of the cities; public relations, 54 per cent; job skills, 47 per cent; techniques of supervision, 45 per cent; and orientation classes for new employees, 37 per cent. In addition, 59 cities conducted municipal management training courses in police, fire, public works, recreation, planning, finance, personnel administration, and the technique of municipal administration offered by the Institute for Training of the International City Managers' Association. Training courses in at least five of the above fields were held by 38 cities and 28 others conducted training in at least four of these fields. Public works department employees in 51 per cent of the cities were given training programs.

Generally, cities scheduled two-hour weekly training sessions on city time and about three-fourths of the reporting cities absorbed the full cost of their training programs. City employees conducted the training programs in 100 cities. The remaining cities employed the outside assistance of university professors, state officials, and/or instructors from local schools.

WATER CONSERVATION—A BY-PRODUCT OF INDUSTRIAL WASTE CONTROL*

By John L. Partin

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Water conservation is not a new topic, particularly in Southern California. Furthermore, there are indications that the emphasis on this subject will increase and demands for regulatory measures will become more insistent within the immediate future. The primary objective of this paper, therefore, is to reiterate and emphasize some statements that have been capably made by others, pertaining to the need for coordinated attention to this problem. For example, in the "Report Upon the Reclamation of Water from Sewage and Industrial Wastes in Los Angeles County, California," prepared in 1949 by a Board of Engineers composed of C. E. Arnold, H. E. Hedger, and A. M. Rawn, the following statements were made:

> Water is the very life blood of Southern California. The story of the struggle for a dependable and adequate water supply is, in effect, the history of Southern California.
>
> The relationship between water supply and population, agriculture, and industry that an area can support is of fundamental significance. As Southern California has grown from the early pueblo days to its present metropolitan status, so has its source of water supply changed from the once flowing Los Angeles River to a system which includes extensive development of local ground waters and importations from the Sierras and the Colorado River.

Ground Water Is Chief Source of Supply

Here it seems appropriate to direct attention again to the fact that at the present time 65 per cent of the water supply for Los Angeles County comes from local aquifers. Importations from the Sierra Nevada Mountains and the Colorado River account for the balance. In the unincorporated portion of Los Angeles County, practically all of the industrial water supply is obtained either from privately owned and operated wells or from private water companies which pump their supplies from the ground. Therefore, it is an established fact that ground water is presently the most important water supply to Los Angeles County industry. Furthermore, the consensus among Los Angeles County industrialists seems to be that a local water supply is the least expensive, provided the depth of pumping does not exceed 1,000 ft. There are cases, however, where fresh water is being pumped from even greater depths. For example, in Kings and Fresno Counties, water is being pumped from depths of 3,000 ft. or more.

Economic Value of Ground Water

The strongest arguments for water conservation, so far as the industrialists are concerned, are to be found in the economics of the problem. Therefore, as a basis for comparison, the sliding water rates of one of the local water companies serving an industrial area have been converted to cost per million gallons instead of the unit of 100 cu. ft. as appears on the water bills. This indicates a cost per million gallons of about $140, based on the rates per 100

* Presented at 25th Annual Convention, California Sewage and Industrial Wastes Assn., Santa Barbara, Calif.; April 22–25, 1953.

cu. ft. of 12½¢ for the first 1,000 cu. ft., 11¢ for the second 1,000 cu. ft., 10¢ for the next 48,000 cu. ft., 9¢ for the next 50,000 cu. ft., and 7¢ for all over 100,000 cu. ft.

Status of Salt-Water Reclamation

Recent reports from the research projects for producing fresh water from the ocean indicate that it might ultimately be possible to produce fresh water from this source for about $500 per m.g., exclusive of any capital or distribution costs. The average cost of pumping water from wells in Los Angeles County is about $15 per m.g.

Relief to Sewer System

Coupled with the water supply problem of Los Angeles County industry is the parallel problem of sewer capacity to receive the liquid wastes. This condition has resulted from unprecedented industrial growth in Los Angeles County to the extent that lateral and trunk sewers in some areas are being loaded beyond their design capacities. An intensive construction program has been undertaken by the Sanitation Districts to remedy these conditions, but presently the demand for sewers is at a faster rate than they can be constructed.

One indication of the value of this sewer capacity is the charge of $35 per m.g. made by the Los Angeles County Sanitation Districts for accepting industrial waste water originating outside the Districts. Several industries have made such arrangements.

An in-place value of $100 per m.g. for water in the natural aquifer, which is reasonable when compared to water charges made by private water companies in Los Angeles County, plus $35 per m.g. for sewer service, makes a combined value of $135 per m.g. for any water saved under such circumstances. To apply these figures to a hypothetical though reasonable case, assume an industrial plant where it is possible to salvage 500,000 g.p.d. of process water by treatment and re-use. A $25,000 investment for treatment and recirculation equipment might be required. On the basis of the combined value of the salvaged water plus sewer service charges, this $25,000 investment would be returned in one year. If only the water value is considered, the amortization period for the $25,000 would be about one year six months. On a five-year basis, the sewage and water saved could amortize a $75,000 installation at 5 per cent interest.

Data on sewage flows made available by the Los Angeles County Sanitation Districts indicate that a radical increase in the sewage flow to the joint sewage treatment plant began during the latter part of 1947. Furthermore, data on water pumped by the Central Manufacturing District of Los Angeles County show a remarkable similarity in characteristics to the sewage flow data just mentioned. Since the water pumped by the Central Manufacturing District is used almost exclusively for industrial purposes, and since the Central Manufacturing District serves a significant part of the industrial areas of the unincorporated section of Los Angeles County, it seems reasonable to conclude that the water demand by industry of this area is a dominant factor in the radical increase in sewage flow. Data on population growth of Los Angeles County as a whole and populations served by the various Sanitation Districts do not correlate with the sewage flow data as does the industrial water demand.

These data are delineated in Figure 1, in which an attempt has been made to present data from various sources to illustrate the dramatic turn of events in the water supply and sewage disposal field during the past decade. These demonstrate the close correlation between sewage flows, water consumption, and receding ground-water levels. Sewage flow rates through the Los Angeles County Sanitation Districts joint disposal plant are indicated by

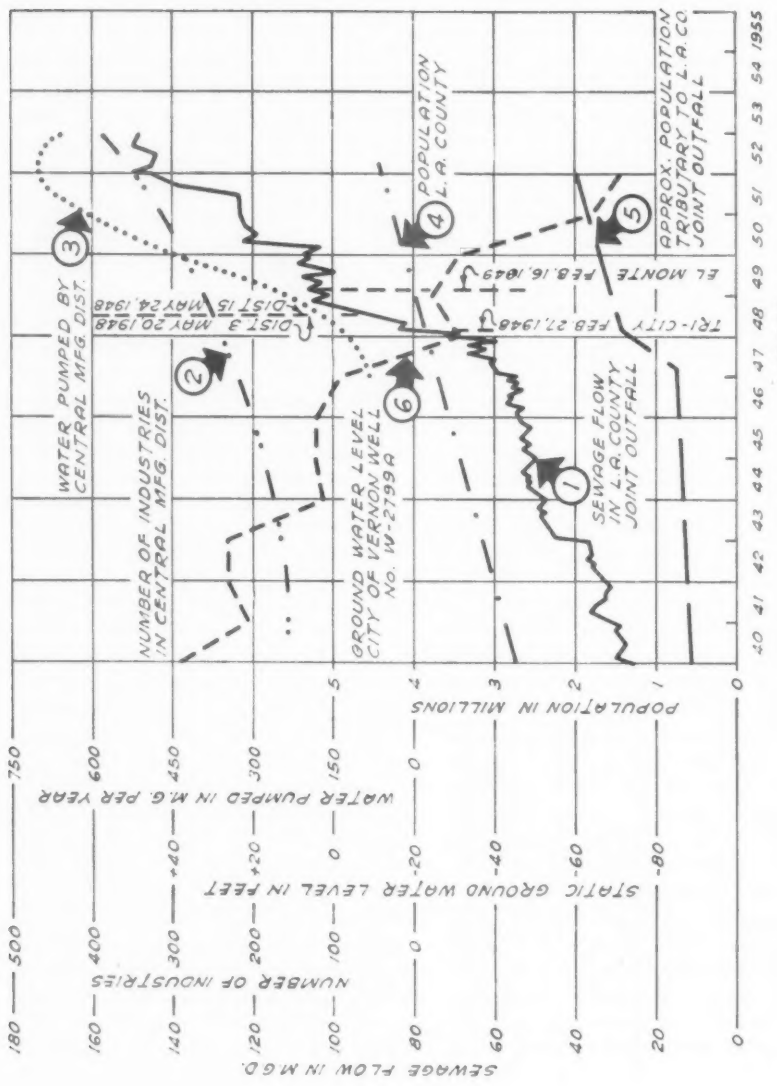
SEWAGE FLOW IN M.G.D.
NUMBER OF INDUSTRIES
STATIC GROUND WATER LEVEL IN FEET
WATER PUMPED IN M.G. PER YEAR
POPULATION IN MILLIONS
YEARS
40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 1955
WATER PUMPED BY CENTRAL MFG. DIST.
NUMBER OF INDUSTRIES IN CENTRAL MFG. DIST.
GROUND WATER LEVEL CITY OF VERNON WELL No. W-2799A
SEWAGE FLOW IN L.A. COUNTY JOINT OUTFALL
POPULATION L.A. COUNTY
APPROX. POPULATION TRIBUTARY TO L.A. CO. JOINT OUTFALL
DIST 3 MAY 20,1948
DIST 15 MAY 24,1948
TRI-CITY FEB. 27,1948
EL MONTE FEB. 16,1949
1
2
3
4
5
6

FIGURE 1.—Comparison of sewage flows, number of industries, industrial water pumpage, populations, and ground-water levels in Los Angeles County.

TABLE I.—Representative Industrial Water Demands in the Los Angeles Area

Industry			Water Requirements				Type of Conservation
			Before Conservation		After Conservation		
Firm Name	Product	Production	(g.p.d.)	(gal./unit)	(g.p.d.)	(gal./unit)	
Kaiser Steel Co.	Steel	—	—	65,000/ton	—	1,400/ton	Re-use of all flows—make-up only for unrecoverable losses due to evaporation, etc.
Lever Brothers	Soap and edible fats	25,000 tons[1]/yr.	1,150,000[2]	7.5/lb.[2]	236,000	1.57/lb.	Recirculation through cooling towers and colloidair separators.
Angelus Paper Box	Paperboard	90 tons/day	660,000[3]	7,333/ton	310,000[3]	3,444/ton	Recirculation of felt wash water and process white water.
Los Angeles Paper Box	Paperboard	50 tons/day	420,000[3]	8,400/ton	204,000[3]	4,080/ton	Recirculation of felt wash water and process white water after passing through save-all.
Latchford—Marble Glass Co.	Glass containers	150 tons/day	100,000[3]	667/ton	17,750[3]	118/ton	Cooling water recirculation.
Maywood Glass Co.	Glass containers	247 tons/day	125,122[3]	507/ton	47,500[3]	192/ton	Cooling water recirculation.
Potlatch Forests, Inc.[4]	Paper tissue	73 tons/day	900,000[3]	12,329/ton	400,000[3]	5,479/ton	Re-use after passing through save-all and diatomaceous earth filters.
Auto-Lite Battery Corp.	Auto batteries, lead grids	—	100,000	—	—[5]	—	Injection of cooling water back into aquifer from which it came.

[1] Long tons. [2] Based on Hammond, Ind., plant operation. [3] 24-hr. operation. [4] Formerly Fernstrom Paper Mills.
[5] Evaporation loss only.

curve 1, which indicates an abrupt increase of flow rate during the latter part of 1947 and the early part of 1948. At about this same time, three annexations were made to the Sanitation Districts' system.

Simultaneously, there was an acceleration in the rate of growth of new industry in the Central Manufacturing District. For information indicative of industrial activity and the amount of water required for these industries, information was obtained from the Central Manufacturing District regarding the number of industries in the District (Curve 2) and the amount of water pumped by the Central Manufacturing District to supply their demands (Curve 3). Furthermore, population statistics were obtained for the past 12 years, both as to Los Angeles County as a whole and the population tributary to the joint outfall system. These are represented by Curves 4 and 5, respectively. To illustrate the dramatic recession of the ground-water level in the vicinity of the Central Manufacturing District, data have been used pertaining to the City of Vernon's water well No. W2799A, whose static water level is represented by Curve 6, which shows that the ground-water level has fallen about 100 ft. during the past 12 years.

In comparing the characteristics of the curves representing the number of industries, population, and water pumped, it is noticeable that the last is more directly correlated with the radical increase in sewage flow than any of the other curves shown. For this reason it is concluded that the industrial water demand is a dominant factor in the increased sewage flow.

With this situation as a background, the Industrial Waste Division of the Los Angeles County Engineer's Office, in collaboration with the County Sanitation Districts, has been promoting a campaign to reduce industrial water demands, thus reducing the draft upon ground-water supplies and at the same time easing the load on the sewer system. It is gratifying to be able to report that these efforts have met with favorable responses, as evidenced by the fact that out of a list of 32 industries which are large water users, 18 have responded with substantial reduction in their water demands to the extent of 1,683,250 g.p.d. within the past two years. Briefly reviewed are a few of the cases dealt with, to illustrate some of the possibilities it is hoped to explore further.

Table I is a basis for comparison of the unit water demands of large consumers in the Los Angeles area with similar industries operating in other parts of the country. Those selected are a few of the most noteworthy cases, either with which the Division has dealt or which have been discussed in current literature. Table II gives further data on industrial water demands.

Steel

The Kaiser Steel Company, at Fontana, Calif., seems to have approached the ultimate in water conservation. This has been accomplished by the complete utilization of the treatment plant effluent. The 1,400 gal. of water per ton of steel represent only the make-up water that must be added to compensate for evaporation and other unrecoverable process losses resulting from 42 re-uses of the water that is pumped from the ground.

Soap

The $25,000,000 Lever Brothers soap and edible oil factory located in the unincorporated East Los Angeles area of Los Angeles County has also demonstrated what can be done in water conservation in that field. Here again, a restricted water supply and limited sewer capacity dictated conditions that had to be met if this plant were to locate in the area. A comparable plant located in the Middle West, where the water supply is unrestricted, uses 2,050

TABLE II.—Water Use Requirements of Oil Refineries, Rubber Plants, and a Food Processing Plant in the Los Angeles Area

Industry	Production	Water Consumption		Remarks
		(m.g.)	(gal./unit)	
(a) Oil Refineries				
General Petroleum—Torrance	120,000 bbl./day[1]	4.048/day	34/bbl.[2]	Based on yearly average; includes all fresh water used.
Richfield Oil Corp.—Watson Refinery	114,000 bbl./day[1]	5.040/day	44/bbl.[2]	Based on monthly average; includes all fresh water used.
Union Oil Company—Wilmington Refinery	110,000 bbl./day[1]	6.052/day	55/bbl.[2]	Based on monthly average; includes all fresh water used.
		46.2/day[3]	420/bbl.[3]	Sea water in cooling towers and heat exchangers.
(b) Rubber Plants—Compounding, Processing				
Goodrich Rubber Co.	5,000,000 lb./mo.	30,000,000 gals./mo.	6 gals./lb.	Includes all water used, domestic and industrial.
Goodyear Tire and Rubber Co.	11,000,000 lb./mo.	28,000,000 gals./mo.	2.54 gals./lb.	Includes all water used, domestic and industrial.
(c) Food Processing				
Kern Food Products, Inc.	18,500 tons/year	2,775,000 gals./year	150 gals./ton	Includes all fresh water used.

[1] Barrels of crude to stills.
[2] Besselievre (1) gives national average as 770 gal. of fresh water per barrel of crude to stills.
[3] Sea water.

g.p.m. or 2,952,000 g.p.d. to produce about 392,000 lb. of soap, or at a rate of 7.5 gal. per pound of soap. The designers of the Los Angeles County plant determined that the ultimate water demand for that plant would be too large for the available supply, and sewer capacity for the waste water was not to be had if the design were based on unrestricted water use. Therefore, to provide for ultimate production and stay within water supply limitations and sewer capacity, their only recourse was to recirculate and re-use water to the limit. Cooling towers in conjunction with oil separators with a capacity of 4,500 g.p.m. for treating cooling and process water for re-use, have been installed. During 1952 production reached about 40 per cent of design capacity. The plant's water consumption for that period was 86,344,750 gal. to produce approximately 55,000,000 lb. of soap and edible oils. This indicates a production water demand of about 1.6 gal. per pound of soap, as compared with 7.5 gal. per pound required by one of the same company's large Eastern plants where water supply is not critical and industrial waste disposal is not restricted, or 5 to 1 reduction.

Paper

The paper industry must always have an abundant and reliable water supply. In Los Angeles County this fact has focused attention in several instances on the urgency for water conservation. One such case is that of the Los Angeles Paper Box and Board Mills plant, which operates its own water well. Since 1941 the static water level has dropped from 67 ft. below the surface to 148 ft., and the drawdown has gone from 105 ft. to 225 ft. below the surface, with some periods when it has dropped to 232-ft. depth. The foot valve, set at 240 ft., did not provide adequate submergence for pump operation under this drawdown condition. Steps are

FIGURE 2.—Dried paper pulp as recovered from bottom of wastes settling basin at Potlatch Forests, Inc., tissue mill.

now being taken to deepen the well and lower the foot valve 40 ft.

Such a situation has not gone unheeded. Two other paper mills have reduced their water usage by clarification and recirculation. The water demands without conservation have ranged from about 17,500 gal. per ton of paper tissue to 7,000 gal. per ton of paper-board products. By re-use of water, these figures have been reduced to the range of 12,500 to 3,400 gal. per ton. The lowest unit demands are possible, of course, where the paper product is such as to tolerate the greatest range in the color factor. Therefore, it has been possible to show a better reduction in the plants that largely manufacture paperboard. However, it is possible that with the installation of equipment to filter the effluent from settling basins (Figure 2) presently being operated by the Potlatch Forests, Inc., paper mills in Pomona, their unit demand may be reduced to 5,400 gal. per ton of paper, which would be an excellent achievement considering the exacting specifications for the paper products manufactured by this firm.

Glass

Two large glass container manufacturing plants have furnished an opportunity to gain an insight into the problem of cooling water for large air compressors. The manufacture of glass containers requires large quantities of compressed air in the cooling and processing of the finished product. The air compressors in turn are cooled with water. Early practice was to use this water once and discharge it to the sewer, but this is contrary to provisions of the Los Angeles County Industrial Waste Ordinance. Therefore, it was necessary for the Industrial Waste Division to take action to abate the violation. The chosen solution was the

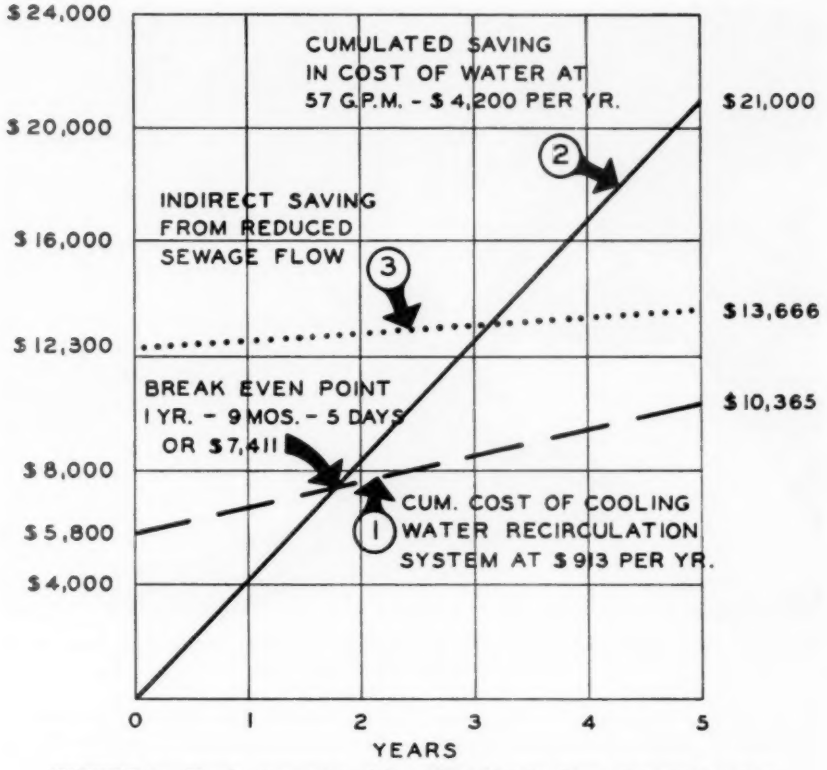

FIGURE 3.—Simple economics of Latchford-Marble Glass Company's water conservation project.

installation of cooling towers with the necessary water recirculating equipment. As a result, these two companies have achieved a substantial economy in their water demands, and the savings in cost of water alone have paid off all expenses in a remarkably short time. Originally, 500 to 700 gal. of water were required per ton of glass. By recirculating the cooling water the demand has been reduced to less than 200 gal. per ton of glass.

In the case of the Latchford-Marble Glass Company, the original requirement was 100,000 g.p.d. of cooling and process water. By installation of a cooling tower and a recirculation system with a capacity of approximately 60 g.p.m., at an initial expense of $5,800, this plant is able to operate with a water demand of only 17,750 g.p.d., thus saving 82,250 g.p.d. At 5 per cent, the firm calculates it spends $913 per year for operation, maintenance, and capital costs. The plant management advises that the annual saving in the water bill is about $4,200. On the basis of these data, the break-even point of costs against savings occurs at the end of one year, nine months. At the end of five years, the over-all saving, after allowing for a complete replacement of the initial installation, is approximately $4,800. These data are delineated in Figure 3.

The economic advantage described is

FIGURE 4.—Injection well for returning cooling water of Auto-Lite Battery Corp. to the aquifer from which it was pumped.

all in favor of the industry. However, the general public does realize a substantial benefit from this conservation activity by (a) relief to the sewer system serving this area and (b) the reduction in the overdraft on the underground water supply.

Oil Refineries

Fresh water is also a vital necessity to oil refineries. It is of interest, however, to note that water conservation is possible in this industry, too, when conditions and economics demand such practice. For example, three of the major oil companies having refineries in Los Angeles County use 4 to 6 m.g.d. each, for a unit water demand of from 34 to 55 gal. per barrel of crude, as compared with 770 gal. of water per barrel of crude oil run to stills in other parts of the country and noted in technical journals. These economies have been attained by the initiative of the engineers of these companies, their decisions to initiate these practices being dictated by the economics involved and the availability of a water supply.

Battery Manufacture

An unusual and interesting method of cooling-water disposal is that of the Auto-Lite Battery Corp., which requires about 100,000 g.p.d. of water. The initial installation at this plant called for a closed system recirculating the water through storage tanks, which were supposed to dissipate the heat energy. However, it was soon found that during the summer months this system was inadequate and the firm was forced to make different arrangements. In this case the industry requested permission to discharge its cooling water, by means of an injection well (Figure 4), back into the aquifer from which it is pumped. The authorities found this solution acceptable, and the firm de-

cided upon this practice after comparing its cost with others, including cooling tower and recirculation equipment. Thus far it has proved successful and is cited as another method to be considered where ground conditions permit.

Acknowledgments

The work described herein was done under the general supervision of William J. Fox, Los Angeles County Engineer and Surveyor, and Arthur Pickett, Industrial Waste Engineer, Office of Los Angeles County Engineer. Thanks also are due many representatives and technicians of industrial and other organizations for their help in assembling the data, as follows: Frank Bowerman and John Parkhurst, Los Angeles County Sanitation Districts; R. E. Sessler, Plant Engineer, Lever Brothers Co.; Stanley C. Adams, Potlatch Forests, Inc. (formerly Fernstrom Paper Mills); F. W. Adams, Los Angeles Paper Box and Board Mills; Glen Henning, Plant Engineer, Maywood Glass Co.; Ivan Duvall, Plant Engineer, Latchford-Marble Glass Co.; R. J. Plummer and William Zolg, Auto-Lite Battery Corp.; and W. I. Hodge, Bulkley, Dunton Processes, Inc.

Reference

1. Besselievre, E. B., "Industrial Waste Treatment." McGraw-Hill Book Co., New York, N. Y. (1952).

REPORT ON COTTON FINISHING WASTE SURVEYS

Analytical surveys on the industrial wastes discharged by two New England cotton finishing mills are presented in a recent report (June, 1953) published by the New England Interstate Water Pollution Control Commission as part of its series on industrial wastes of the area. One of the mills studied is located in Connecticut, the other in Rhode Island.

The Connecticut survey showed that 67,000 gal. of water were required for processing each 1,000 lb. of cloth. In this plant only 28 per cent was dyed, the remainder being printed. The waste produced contained 220 p.p.m. B.O.D. and 442 p.p.m. total alkalinity. Of the B.O.D, 35.3 per cent was contributed by desize operations, 31.0 per cent by kiering, 1.3 per cent by mercerizing, and 5.5 per cent by dyeing. The cloth processed average 0.56 lb. per yard, the total population equivalent calculating to 738 per 1,000 lb. of cloth finished. Of the alkalinity, 30.8 per cent was contributed by kiering, and 24.7 per cent by mercerizing. In this plant 23 wastes contained 40 per cent of the flow, 78 per cent of the B.O.D., 76 per cent of the alkalinity, and 95 per cent of the acidity.

For the Rhode Island plant, the survey indicated that no cloth was printed, but all was either bleached white or dyed. The cloth in this case weighed 0.25 lb. per yard. Of the total flow, 45 per cent was contained in 36 individual wastes that also contained 84 per cent of the B.O.D., 93 per cent of the alkalinity, and 96 per cent of the acidity.

These results indicate that segregation should certainly be carried out if treatment of the plant wastes is necessary.

The report also gives detailed analyses of all the waste components for both mills, and a process chemical inventory and B.O.D. survey for the industry. Authors of the report are M. G. Burford and J. W. Masselli, Wesleyan University, Middletown, Conn.; W. J. Snow, Connecticut State Water Commission; and Henry Campbell and F. J. DeLuis, University of Rhode Island, Kingston, R. I.

OXIDATION OF COTTON KIER WASTES

By Nelson L. Nemerow

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Many textile mills are still plagued with the problem of disposing of the highly alkaline and pollutional wastes resulting from the cooking, bleaching, and washing of raw stock or used cotton goods. Some mills discharge relatively small volumes of wastes into municipal sewers and treatment plants; others discharge the wastes without treatment into the receiving stream. Few mills attempt to treat this waste themselves. The reason for this is not entirely due to the lack of restrictive pollution laws and education of the mill personnel, but is, at least in part, due to the high cost and accompanying operational difficulties which exist in the present treatment methods.

It is the purpose of this paper to present what is believed to be an economical and practical method of treating cotton kier wastes.

Origin and Volume of Wastes

Pretreated cotton goods are loaded into cooking vessels known as "kiers" and cooked under pressure (corresponding to temperatures of about 270° F.) for about 8 hr., generally with caustic soda, a detergent, and an alkaline phosphate. The kiers are then blown out and the cotton is washed for a short time with water. Bleach (peroxide or chlorine) and alkaline silicates and phosphates are again added to the kier and the contents are steamed at about 180° F. for 4 hr., following which the contents are once again blown out and the goods are washed with water. Actually, therefore, the combined kier liquor waste is made up of three components, as follows:

Component	Volume [1] (gal.)
Caustic soda waste	25.0
Bleach waste	16.3
Wash water waste	4.4
Total	45.7

[1] As found in typical North Carolina mill, in gallons per 100 lb. of cloth processed.

Review of Pertinent Literature

Southgate (1) refers to this waste as the most polluting one in the manufacture of unbleached cotton yarn or fabric. Geyer and Perry (2) found that for each 100 lb. of goods kiered and washed, the mixed wastes contained from 1.6 to 2.0 lb. of B.O.D. and a population equivalent of 9.7 to 12 persons. However, liquors produced in the kiering of waste cotton, which is usually dirty and may be oily, are much more polluting in character. Methods of treatment which have been tried include neutralization, addition of coagulants, biological filtration, and evaporation.

Neutralization

Wilson and Calvert (3) reported experiments in which the value of the oxygen absorbed from potassium permanganate by the soluble constituents of spent liquors from boiling of cotton with soda ash was reduced about 50 per cent by neutralization of the liquor with sulfuric acid. The Royal Commission (4) recommended treatment of kier liquors with carbon dioxide, but found in laboratory experiments that carbonation occurred only slowly. They suggested that the liquors might be passed down a contact tower against a current of flue gases. This process

was further examined by Copson and Curtis (5), who saturated the waste liquors with carbon dioxide, added a measured volume of untreated kier liquor to convert the bicarbonates to carbonates, and finally added calcium chloride in excess to react with the sodium carbonate, the calcium carbonate then being removed by sedimentation. They claim a reduction of 75 to 80 per cent. According to Geyer and Perry (2), the cost of this treatment in America in 1936 was estimated to be nearly $1 per 1,000 gal. (Imp.) for a plant handling about 35,000 g.p.d. (Imp.)

When stored in a lagoon, kier liquor takes up CO_2, partly by absorption from the air and partly as a result of bacterial oxidation; in some American experiments (6) complete carbonation in liquid 1 ft. in depth took 3 to 4 weeks.

Coagulation

Porges, Horton, and Gotaas (7) showed in pilot plant studies that partial purification of spent kier liquors can be achieved with coagulants. B.O.D. and color reductions were in the range of 70 to 80 per cent when ferrous sulfate, calcium chloride, alum, or alum and lime were used as coagulants. However, the coagulant dosages were high (2 to 4 per cent), the pH ranges narrow, the sludge quantities great, voluminous, and unsettleable. These facts make the treatment expensive and operationally difficult. Campbell's studies (8) showed that the waste did not respond to coagulation with calcium chloride, alum, or ferrous sulfate. Sulfuric acid produced precipitation, but the results were not satisfactory. These preliminary studies confirm the work of Worth (9). Campbell (8) also states that although the method of Copson and Curtis (5) reduced the pH from 11.5 to 7.4, the oxygen consumed by 16.6 per cent, and the color by 50 per cent, and produced a good, fast-settling precipitate, the resulting effluent cannot be considered satisfactory. Campbell (8) found that precipitation of the sodium carbonate by converting to calcium carbonate with lime, plus precipitation of the supernatant liquor, containing only NaOH, also was unsuccessful. The floc formed was too light and did not settle readily, and the supernatant showed little improvement over the raw waste. He concluded that there was no satisfactory method available for the chemical precipitation of kier liquors. He also concluded that the chlorination of the waste resulted in a better effluent than obtained by any other chemical treatment, but that the results obtained up to that time could not yet be considered satisfactory despite a 35.3 per cent reduction in oxygen consumed and an 80 per cent reduction in color.

Biological Treatment

Untreated kier liquor is much too alkaline for effective purification in percolating filters, but it is reasonable to assume that neutralized and diluted liquor could be treated by biological filtration to give an effluent of good quality. In small-scale tests the Royal Commission (4) maintained a mixture of waste liquors from lime and soda kiers in contact with sewage, diluted the mixture with four times its volume of water, and treated the liquid so obtained in a small percolating filter at a rate of 80 g.p.d. per cu. yd.; the filter effluent was then treated in a second small filter at a rate of 56 g.p.d. per cu. yd. The values for oxygen absorbed from permanganate were: liquid applied to first filter, 401 p.p.m.; effluent from first filter, 48 p.p.m.; and final effluent, 31 p.p.m.

Campbell (8) concluded from his biological trickling filter studies that the treatment of 10 per cent kier liquor, neutralized to pH 7.3, and 90 per cent sewage on a trickling filter, at the rate of recirculation of 42 m.g.a.d., will produce a good clear effluent with 16-hr. recirculation. It was his opinion that

TABLE I.—Average Raw and Treated Kier Waste Characteristics

Item	Raw Waste	Treated Waste	
		Unseeded	Seeded
pH	12	8.2	8.3
Alk. (p.p.m. as $CaCO_3$)	2,174	869	906
Color	Brown	Tan	Tan
Turbidity (p.p.m.)	205	813	712
Total solids (p.p.m.)	6,323	5,275	4,908
Tot. vol. sol. (p.p.m.)	2,830	2,037	1,709
(%)	44.5	38.5	34.8
Total ash (p.p.m.)	3,493	3,238	3,299
(%)[1]	55.5	61.5	65.2
Tot. susp. sol. (p.p.m.)	55	—	—
Vol. susp. sol. (%)	90	—	—
Tot. diss. sol. (%)[1]	99	—	—
Diss. vol. (p.p.m.)	2,777	—	—
(%)[2]	44.1	—	—
Dissolved ash (p.p.m.)	3,491	—	—
(%)[2]	55.9	—	—
B.O.D., 5-day (p.p.m.)	2,140	695	507
Ratio, vol./B.O.D.	1.3:1	2.93:1	3.37:1

[1] As percentage of total solids.
[2] As percentage of dissolved solids.

a satisfactory effluent may be developed with concentrations of kier liquor above 20 per cent.

Laboratory Oxidation Procedure

Samples of kier waste were neutralized with dilute hydrochloric acid to pH 9.0. Ammonium chloride was added in sufficient quantity to assure a B.O.D. to ammonia-nitrogen ratio of 20 to 1. Then small quantities of waste were added to domestic sewage and the mixture aerated for 24 hr. At the end of this period the mixture was settled and a portion of the supernatant was added to a new mixture of neutralized (pH 9.0) and nitrogen-fortified waste and a decreasing amount of sewage. The new mixture was then aerated for 24 hr. and the procedure repeated. After each 24 hr. of aeration the volume of sewage added was decreased and the volume of supernatant returned was increased. At the end of a week no sewage was added and a mixture of 50 per cent kier waste and 50 per cent returned supernatant comprised the aerating mixture. The unseeded samples received the same pretreatment, except that no sewage was added at any time. Table I gives the average characteristics of both the seeded and unseeded wastes.

Discussion

Comparison of Treated and Raw Kier Wastes

Reduction of the pH from 12 to 8.3 makes the waste more comparable to domestic sewage and permits it to be handled in the municipal sewer. Likewise, the color and alkalinity have been reduced from brown and 2,174 p.p.m., respectively, to tan and 906 p.p.m. On the other hand, the turbidity increased considerably (from 205 to 712 p.p.m.) This was due partly to the tendency of the alkaline-soluble substances to come out of solution into the dispersed state when the pH was lowered to 8.3, and partly to some minute unsettleable biological growth that occurs during aeration. The total solids reduction after aeration was 22 per cent. This was mainly due to a loss in organic solids, which were oxidized during the aeration process. The volatile solids dropped from 44.5 to 34.8 per cent of the total solids concentration. The loss in volatile solids accounted for the B.O.D. reduction from 2,140 to 570 p.p.m.

It was also of interest to note that although the ratio of organic matter to B.O.D. in the raw waste was 1.3 to 1, the ratio was increased to 3.37 to 1 in the treated effluent. This indicated that the organic matter was more stable in the treated waste, and consequently would not decompose easily in the rivers.

Comparison of Seeded and Non-Seeded Treated Kier Wastes

The pH, color, and alkalinities of the seeded and non-seeded effluents were very similar. However, the turbidity and solids concentration were slightly higher in the unseeded effluents. The fine biological growth removed some turbidity when settled out. The volatile solids concentration was 328 p.p.m.

higher in the unseeded and aerated kier waste effluent. The higher organic solids were undoubtedly the reason for the B.O.D. of 695 p.p.m. as compared to 507 p.p.m. in the seeded and aerated kier waste effluent. The treatment, therefore, effected B.O.D. reductions of 77 and 68 per cent in the seeded and unseeded kier waste effluents, respectively. These results showed that almost as efficient oxidation occurred in the unseeded and aerated samples as was obtained by careful seeding and similar aeration. The indication is, therefore, that either the oxidation is mainly chemical, or seed already present in the waste or contaminated from the air during aeration alone is sufficient for the oxidation to proceed. A sludge volume of 10.3 per cent resulted from the seeded waste, whereas only 0.3 per cent occurred in the non-seeded waste. The biological activity in the seeded waste was certainly proven by the sludge formed. The absence of this excess sludge and a considerable B.O.D. reduction make aeration in the absence of adapted seed more desirable from an operational standpoint.

Cost of Treatment

On the basis of 36,560 g.p.d. of kier waste (80,000 lb. of cloth processed), the laboratory studies indicate that the capital cost of the necessary aeration tank would be about $5,500 and the required 250-c.f.m. (5 p.s.i.) compressor would cost about $2,500. Operating costs are estimated as follows:

1. Neutralization to pH 9 with sulfuric acid @ $0.01 per lb., $3.91 per day.
2. Ammonia-nitrogen addition (ammonium nitrate) @ $0.0362 per lb. in carload lots, $3.51 per day.
3. Power (10-hp. motor) @ $0.0125 per kw.-hr., $2.24 per day.

The total capital cost, therefore, is estimated at $8,000; the total operating cost is estimated at $9.66 per day with complete ammonia-nitrogen addition, or $6.15 per day without ammonia-nitrogen addition.

Summary and Conclusions

An applied research to determine the effect of aeration on the pollutional load reduction of cotton kiering wastes was carried out in the Sanitary Engineering Laboratories at North Carolina State College. The volume and sanitary characteristics of the kiering liquor wastes were determined. The results of the treatment studies showed that B.O.D. reductions of 77 per cent were obtained at room temperature (25° C.) when the wastes were neutralized, mineralized with ammonium salts, properly seeded with biological growth, and aerated for 24 hr. However, reductions of 68 per cent were also obtained with aeration and without the aid of biological adapted seed material. Maximum operating costs of $0.012 per 100 lb. of cloth processed and capital costs of $0.10 per pound of cloth capacity were estimated for this treatment.

Specific conclusions are as follows:

1. Alkaline and highly pollutional kier liquor wastes arising from the cooking, bleaching, and washing of cotton goods amounted to 45.7 gal. per 100 lb. of cloth processed.
2. The pollutional characteristics of the raw waste include a pH of 12, alkalinity of 2,174 p.p.m., brown color, and a 5-day B.O.D. of 2,140 p.p.m.
3. Aeration for 24 hr. at 20° to 25° C., following neutralization, ammonium salt addition, and seed adaptation, effected a B.O.D. reduction of 77 per cent.
4. Aeration for 24 hr. at 20° to 25° C., following only neutralization and ammonium salt addition, resulted in a B.O.D. reduction of 68 per cent.
5. The daily operating cost under (3) is estimated at $9.66 per day and under (4) at $6.15 per day, assuming the salt can be eliminated.

6. The capital cost for a plant processing 80,000 lb. of cloth per day is estimated at approximately $8,000 for the treatment of kier wastes of similar characteristics.

References

1. Southgate, B. S., "Industrial Waste Waters." P. 190. H. M. Stat. Office, London, Eng.
2. Geyer, J. C., and Perry, W. A., "Textile Waste Treatment and Recovery." Textile Found., Inc., Washington, D. C. (1936).
3. Wilson and Calvert, "Trade Waste Waters." Griffin and Co., London, Eng. (1913).
4. Royal Commission on Sewage Disposal, "Ninth Report." Vol. 1. London, Eng. (1915).
5. Copson, R. L., and Curtis, H. A., "Calcium Chloride and Flue Gas Used in Novel Process for Waste Disposal." *Chem. and Met. Eng.*, **37**, 167 (1930).
6. "Annual Report of Department of Public Health." Pub. Doc. 34, Publ. of Commonwealth of Mass., Boston (1937).
7. Porges, R., Horton, R. K., and Gotaas, H. B., "Chemical Precipitation of Kier Liquor Waste." *Sewage Works Jour.*, **14**, 3, 685 (May, 1942).
8. Campbell, M. S., "Disposal and Recovery of Textile Wastes." Textile Found., Inc., Washington, D. C.
9. Worth, A. M., "Studies on the Treatment of Combined Textile Wastes and Domestic Sewage." Thesis, Univ. North Carolina (1928).

SPECIALTY BOARD FOR SANITARY ENGINEERS RECOMMENDED

To obtain desired certification of sanitary engineers, the Joint Committee for Advancement of Sanitary Engineering, a grouping of representatives of five major organizations in the field, has recommended use of the facilities of the American Society of Civil Engineers and the Engineers' Joint Council. After detailed study of numerous proposals for enhancing the recognition of sanitary engineers, action was taken, during a July meeting of the committee in Washington, recommending steps to be taken in establishment of a Specialty Board.

As proposed, a certification board of five members, as recommended by the joint committee, will be appointed by the Board of Direction of ASCE. Ultimately, both the joint committee and the specialty board are proposed to become administrative functions of Engineers' Joint Council, because of the cooperative interest of several professional organizations in the program. Functions of the board members will be augmented by appointed consultants.

Upon application by individuals and satisfactory evidence of professional ability in the field of sanitary engineering, certificates will be issued. Those so certified will be designated members of an American Academy of Sanitary Engineers. It is not proposed that this academy hold meetings, issue publications, or in other manner further duplicate such activities now conducted by existing organizations, the sole purpose being recognition of those certified by the specialty board. Modest expense for operation of the board, issuing of certificates, and maintenance of a roster will be defrayed by collection of a fee for certification.

Before this proposal can become a reality, endorsement of the ASCE Sanitary Engineering Division and approval by the ASCE Board of Direction are needed. Before EJC can administer the program, adoption of the proposal by that Council is required.

Represented on the joint committee which produced this proposal are: American Public Health Association, American Society of Civil Engineers, American Society for Engineering Education, American Water Works Association, and Federation of Sewage and Industrial Wastes Associations.

As a definition of sanitary engineering, the joint committee adopted the statement prepared by the Committee on Sanitary Engineering of the National Research Committee in October, 1943.

Stream Pollution

COMPUTATION OF POLLUTION IN A VERTICALLY MIXED ESTUARY *

By Henry Stommel

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Papers recently published by Ketchum (1) and Arons and Stommel (2) have presumed to give a theoretical account of the distribution of fresh water in an estuary. Pritchard (3), however, justly has pointed out that these treatments are at best applicable only to estuaries so intensely tidally mixed that they exhibit no vertical stratification. In such cases the salt is carried upstream against the main river flow by turbulence. Ketchum proposed a mixing process, which he called "exchange ratio," and was able to compute the salinity distribution in the Raritan. Using the published data (4) on the Severn estuary, the author and Harlow G. Farmer found that the method of the "exchange ratio" gave a grossly incorrect salinity distribution. Inasmuch as the Severn is unstratified, and appears to fit all the requirements of Ketchum's analysis, it is quite clear that the method of the exchange ratio is not nearly so general as was proposed.

The method of Arons and Stommel (2) is open to similar objections. The Severn salinities can be plotted on the family of curves given in that paper, but it is found that the mixing length is of the order of magnitude of the depth, or about 1/1000th of the tidal excursion. This discrepancy suggests that, at least so far as the Severn is concerned, the hypothesis about the mixing length made by Arons and Stommel does not hold in general. In short, it does not appear likely that any good purpose can be served at present by making *a priori* suppositions about the turbulent mixing process. From a practical point of view the proper procedure is to use the distribution of river water as a means of discovering the magnitude of the turbulent diffusion coefficients at various places in the estuary, and to devise a method using these coefficients which will yield the dilution of pollution at any point in the estuary. An attempt at such a method is described in the following. It is important to re-emphasize that it is intended to apply only to vertically unstratified estuaries in which the mixing is due to tides.

Steady-State Equations

In considering an estuary such as that shown in Figure 1, it is assumed that the x-axis is directed along the axis of the channel; also that the cross-sectional area, $S(x)$, may vary with the position along the axis.

Now it is supposed that a pollutant, which is miscible with water, whose average (over a tide) concentration, $c(x)$, varies with x, is in a steady-state distribution in the estuary. By the term "steady state" is meant that the average of the concentration c over a tidal cycle does not change from tide to tide. This will be true if there has been little change in the river discharge during the time involved, and the discharge of pollutant into the estuary has remained constant. If the total river discharge into the estuary, at some point remote in the $-x$ direction, is Q, then the flux of pollutant by advection toward the sea is $Q\,c$.

* Contribution No. 640 from the Woods Hole Oceanographic Institution.

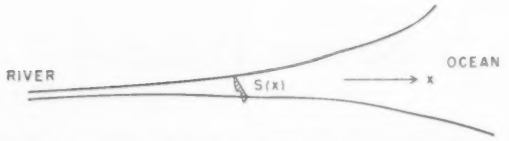

FIGURE 1.—Basic dimensions for estuary computations.

In addition, there is a turbulent flux due to the tidally-produced turbulence in the estuary. This turbulent flux may be written in the customary fashion; that is, $-SA\,dc/dx$, where $A(x)$ is a turbulent eddy diffusivity, the value of which must be determined before the distribution of the pollutant can be calculated. Contrary to the methods of Ketchum (1) and of Arons and Stommel (2), A is not specified *a priori*.

The net seaward flux, $F(x)$, of pollutant across any section is the sum of these two fluxes; that is,

$$F(x) = Qc - SA\frac{dc}{dx} \qquad (1)$$

If the pollutant is conservative (does not decay with time), the net flux, $F(x)$, must be constant downstream of the source of pollutant, and must be zero upstream of it. Some important pollutants, such as bacterial and atomic pile wastes, are not conservative, and their concentrations decay even when not subject to the dispersing influence of the estuary.

The concentration of such a non-conservative pollutant in an isolated container, may decrease with time according to the exponential decay law—

$$c = c_0 e^{-t/\tau} \qquad (2)$$

—in which τ is the time required for the concentration to decay from the concentration c_0 to c_0/e. The time, τ, is slightly larger than the half-life of the pollutant, or

$$0.693\tau = \text{(half-life)}$$

The net flux, $F(x)$, cannot be the same for all values of x if the pollutant is non-conservative, but must diminish in the following manner:

$$\frac{d}{dx}F(x) = -\frac{S}{\tau}c \qquad (3)$$

The steady-state equation (Eq. 1) may be written in the form

$$\frac{d}{dx}\left[Qc - SA\frac{dc}{dx}\right] + \frac{S}{\tau}c = 0 \qquad (4)$$

or

$$\frac{d}{dx}\left[Qc - SA\frac{dc}{dx}\right] + \frac{S}{\tau} = \psi \quad \text{at outfall} \qquad (4a)$$

where ψ is the total rate of pollutant supply at the outfall.

For a given pollutant and given estuary it is evident that the quantities Q, S, and τ are known. If A can be determined, then the distribution of $c(x)$ should be easily calculated.

Determination of the Eddy Diffusivity

The eddy diffusivity, A, may be computed from a knowledge of the concentration of any other property in the estuary. The concentration of fresh water, $f(x)$, is a convenient conservative property. In some estuaries where ground water, or precipitation, or evaporation, is important, it might be almost impossible to use the concentration of fresh water as a means of computing A. Let it be supposed for the immediate purpose that all the fresh water comes from one river, and that little is added or subtracted by other means. How to treat more complicated cases will be evident when the principles for this simple case are understood.

If the concentration of fresh water, f, is written for c in Eq. 1, the equation

takes the following form because in this case $F(x) = Q$:

$$A = \frac{Q(f-1)}{S\,df/dx} \tag{5}$$

The concentration of fresh water, f, is dimensionless (for example, pure fresh water is represented by 1.0; a mixture of one part fresh water and three parts sea water, is given by $f = 0.25$, etc.) The river discharge, Q, is in cubic feet per second; the cross-sectional area, in square feet; and distance in the x direction, in feet. The dimensions of the eddy diffusivity A are, therefore, in square feet per second.

The easiest way to compute A is to segment the estuary along its axis, the intervals being equally spaced a feet apart (Figure 2).

The average value of f is indicated at each segment. Eq. 5 may now be written in finite difference form for numerical computation:

$$A_n = \frac{Q2a(1-f_n)}{S_n(f_{n-1}-f_{n+1})} \tag{6}$$

In general, f_n is less than unity, and f_{n+1} is less than f_{n-1}, so that A_n is expected to be positive. The values of A_n at points far upstream (where $f_n \to 1$ and $f_{n-1} \to f_{n+1}$), are indeterminate from the fresh-water distribution; this is also true beyond the mouth of the estuary in the ocean.

Calculation of the Concentration of Pollutant

Eq. 4 is written in finite difference form and the various coefficients gathered together, as follows:

$$P_n c_{n-1} + Q_n c_n + R_n c_{n+1} = 0 \tag{7}$$

in which

$$P_n = -\frac{1}{2a}\left[Q - \left(\frac{A_{n+1}S_{n+1} - A_{n-1}S_{n-1}}{2a}\right)\right] - \frac{A_n S_n}{a^2}$$

$$Q_n = \frac{2A_n S_n}{a^2} + \frac{S_n}{\tau}$$

$$R_n = \frac{1}{2a}\left[Q - \left(\frac{A_{n+1}S_{n+1} - A_{n-1}S_{n-1}}{2a}\right)\right] - \frac{A_n S_n}{a^2}$$

Eq. 7 must hold at each of the segments, with one exception. In addition, there are certain additional constraints. At the ocean, where $f = 0$, the value of $c = 0$; also, far upstream $c = 0$. At the segment where the outfall of the pollutant is located one further condition is imposed: the difference in flux upstream and downstream must be equal to the total rate of input of pollutant ψ. The segment at which the source (outfall) of pollutant is nearest may be designated as $n = s$.

In place of Eq. 7, which holds at all points except at $n = s$, the equation at $n = s$ becomes

$$P_s c_{s-1} + Q_s c_s + R_s c_{s+1} = \frac{\psi}{2a} \tag{7a}$$

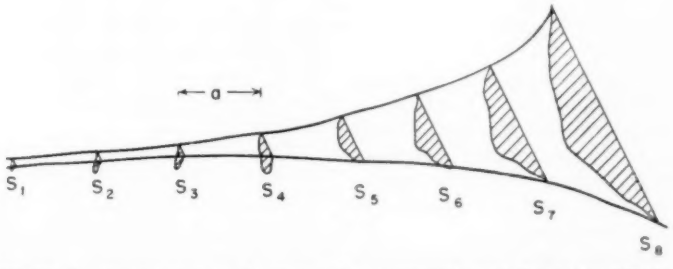

FIGURE 2.—Segmentation of estuary for computation of the eddy diffusivity.

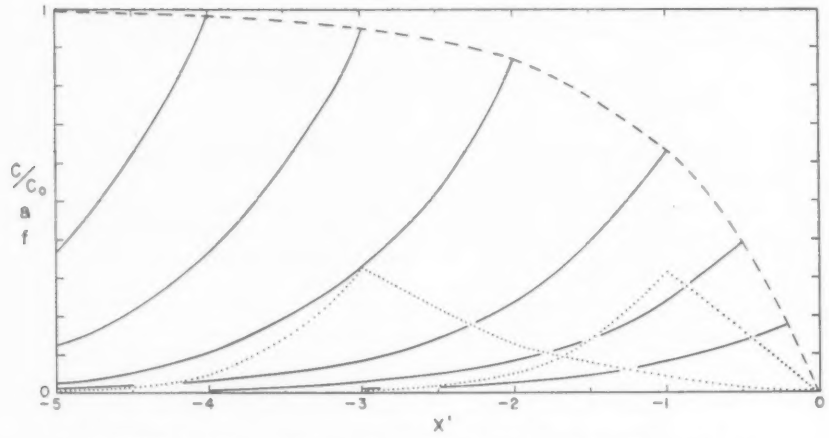

FIGURE 3.—Plot of computation results for estuary of uniform section.

The equations having been obtained, the solution is easily carried through by relaxation methods.

Simple Example, Estuary of Uniform Section

Before proceeding with a numerical example, it may be of interest to consider a simple example to illustrate certain fundamental properties of the problem. An example is chosen which admits an analytical solution.

Consider an estuary of uniform cross section, S, which opens abruptly into the sea at $x = 0$. If the eddy diffusivity, A, is a constant, then the concentration of fresh water has a very simple analytical form:

$$f = 1 - e^{x'} \tag{8}$$

in which

$$x' = \frac{Q}{AS}x$$

The water is entirely fresh far upstream ($f = 1$), but diminishes to $f = 0$ at the mouth, as shown by the dashed line in Figure 3. In this graph the distance along the estuary is plotted in dimensionless units, x', the value being negative within the estuary.

Now consider the concentration of pollutant due to an outfall at $x = L$. The analytical solution of Eq. 4 is composed of two separate parts:

$c_1(x)$ applies upstream of the outfall;
$c_2(x)$ applies downstream of the outfall;

and

$$\frac{c_1(x)}{c(L)} = e^{k_1(x'-L')} \tag{9}$$

$$\frac{c_2(x)}{c(L)} = \frac{e^{k_2x'} - e^{k_1x'}}{e^{k_2L'} - e^{k_1L'}} \tag{9a}$$

in which

$$c(L) = c_0(e^{k_2L'} - e^{k_1L'}),$$
$$k_1 = \tfrac{1}{2}(1 + \sqrt{1 + Z}),$$
$$k_2 = \tfrac{1}{2}(1 - \sqrt{1 + Z}),$$
$$Z = 4AS^2/(\tau Q^2),$$

and

$$c_0 = \psi/Q, \quad L' = \frac{Q}{AS}L$$

The quantity c_0 is the concentration of pollution which would result at the outfall if there were no diffusion or decay; in other words, the simple dilution by river flow alone.

Figure 3 displays certain of these solutions. The abscissa is expressed in a dimensionless fashion. The ocean is located at the extreme right-hand side. Toward the left is the upstream direction. The dashed line is the solu-

tion of Eq. 8 for the concentration of fresh river water, f. The solutions of the problem of the distribution of a conservative pollutant introduced at $x' = -4, -3, -2, -1, -0.5$, and -0.2 are shown as solid black curves, terminating at the dashed curve at each of the outfall locations respectively. The remainder of the solution (downstream of the outfall) falls along the dashed line. The peak concentration is at the outfall. It is immediately clear, then, in this simple case of an estuary of uniform cross-section and eddy-diffusivity, that the pollution extends far upstream of the outfall, no matter what the location of the outfall, but that the concentration is everywhere reduced upstream of the outfall if the location of the outfall is moved toward the sea.

A seaward displacement of the outfall also reduces the peak concentration at the outfall, but downstream the concentration of a conservative pollutant is not affected by such a displacement.

The dotted curves in Figure 3 represent solutions for a non-conservative pollutant whose decay time is

$$\tau = AS^2/(2Q^2)$$

for outfall locations at $x' = -3$ and -1. The remarkable feature of these curves is that the peak concentration, even at the outfalls, is much reduced from what it is in the case of the conservative pollutant. The general equation for the peak concentration is

$$\frac{c(L)}{c_0} = \frac{1}{\sqrt{1+Z}}\left(1 - e^{L'\sqrt{1+Z}}\right) \quad (10)$$

The non-conservative pollutant extends both upstream and downstream of the outfall, but, unlike the conservative

TABLE I.—Numerical Example of Pollution Computation

n	S_n (1,000 sq.ft.)	f_n	A_n sq.ft./sec.	P_n	O_n	R_n	c_n*	X_n	c (lb./cu.ft. $\times 10^6$)
0	7.7	1.000	—	—	—	—	—	—	—
1	7.7	1.000	—	—	—	—	—	—	—
2	8.9	0.929	180	—	—	—	—	—	—
3	8.2	0.840	280	−0.147	0.062	0.100	—	—	—
4	12.8	0.679	290	−0.134	0.099	0.080	—	—	—
5	15.4	0.536	500	−0.182	0.184	0.029	—	—	—
6	14.0	0.465	960	−0.237	0.296	−0.032	0	—	0
7	18.0	0.393	1,040	−0.282	0.410	−0.191	1	0.0	0.05
8	27.3	0.350	1,000	−0.377	0.601	−0.169	2	+0.1	0.1
9	75.0	0.308	390	−0.419	0.735	−0.166	4	−0.1	0.2
10	102.0	0.265	280	−0.384	0.781	−0.192	13	0.0	0.6
11	84.0	0.215	510	−0.464	1.024	−0.393	44	+0.7	2.2
12	117.0	0.200	570	−0.793	1.567	−0.533	100	+95.9	5.0
13	151.0	0.172	270	−0.496	1.123	−0.236	48	−0.4	2.4
14	254.0	0.125	192	−0.572	1.487	−0.406	21	−0.4	1.1
15	285.0	0.108	210	−0.656	1.767	−0.541	8	0.0	0.4
16	410.0	0.072	190	−0.274	2.378	−1.283	1.5	—	0.07
17	424.0	0.065	740	−2.714	7.123	−3.560	0.7	—	0.03
18	525.0	0.061	570	−2.937	7.035	−2.676	0.5	—	0.02
19	855.0	0.059	280	−2.468	6.498	−2.321	—	—	—
20	1,091.0	0.046	295	−3.147	8.618	−3.290	—	—	—
21	1,372.0	0.043	234	−3.139	9.168	−2.879	—	—	—
22	1,268.0	0.036	190	−2.218	7.357	−1.958	—	—	—
23	1,748.0	0.029	110	−1.942	7.341	−1.682	—	—	—
24	2,070.0	0.018	95	−2.078	8.073	−1.855	—	—	—
25	2,496.0	0.011	80	—	—	—	—	—	—
26	2,915.0	0.000	—	—	—	—	—	—	—

* Arbitrary units.

pollutant, can be reduced at a point below the outfall by an upstream displacement of the outfall.*

Consideration of this simple case also shows clearly the effect of a change in the river discharge, Q. Increase of river discharge increases the fresh-water concentration at every position, foreshortens the extent of pollution upstream, reduces the peak concentration of pollution at the outfall, and even reduces the concentration of a conservative pollutant downstream.

Numerical Example

As an example of computation of concentration of pollution by numerical methods, a particular distribution is computed for the Severn estuary, for which good salinity data are available (4). Stations are chosen beginning at Gloucester ($n = 0$); the sections are spaced about 2 mi. apart ($a = 10{,}000$ ft). Cross-section areas are given in Table I, in the column headed S_n. The fresh-water concentration, f_n, from actual summertime survey data, is also tabulated.

The eddy diffusivity, A_n, is computed at each station by Eq. 6, using a value of $Q = 360$ cu. ft. per sec. as the fresh-water discharge during the summer dry period. It is interesting to note that the highest values of A_n occur at Stations 6, 7, and 8, which happen to be the location of the Severn bore.

Suppose now that a pollutant outfall is located at Sharpness ($n = 12$), and that this pollutant has a half-life of 4 days ($\tau = 5 \times 10^5$ sec.) The coefficients P_n, Q_n, and R_n of Eq. 7 are tabulated in Table I. An estimated distribution of pollutant is initially entered into Table I, and the sum $\bar{X}_n$ (called the residual) is formed:

$$P_n c_{n-1} + Q_n c_n + R_n c_{n+1} = \bar{X}_n \quad (11)$$

Eq. 7 requires that all residuals except that at the outfall should vanish. In fact, it is seen that this is far from true for the estimated pollution distribution. The values of c_n can be adjusted by successive steps (relaxation method) because it is obvious that if Δc_n units are added to any c_n, not only will the residual $\bar{X}_n$ be changed by the addition of $Q_n \Delta c_n$, but also the residual $\bar{X}_{n+1}$ will be increased by $P_{n+1} \Delta c_n$ and the residual $\bar{X}_{n-1}$ by $R_{n-1} \Delta c_n$. These adjustments are made step by step, removing the worst residuals first, and from time to time recomputing the residuals from the newly adjusted c_n by Eq. 11. When the residuals have all been reduced to a point where further readjustments of c_n are below the precision of the required result (say 1 to 5 per cent), the relaxation procedure may be regarded as completed: namely, a set of values of c_n has been obtained which satisfy Eq. 7. In the example shown, 54 adjustments of c_n were necessary in all. The computation took about 3 hr. Arbitrary units have been used for c_n, which must now be converted to units of actual pollution concentration. If it be supposed that the discharge of pollutant at Station 12 is 10 lb. per sec., the concentration due to dilution by a river flow of 360 cu. ft. per sec. alone (if there were no diffusion or decay) would be 28×10^{-3} lb. per cubic foot.

The value of $\bar{\psi}$ (= 10 lb. per sec.) is put into Eq. 7*a*. Then $\bar{\psi}/2a$ should be equal to the residual, $\bar{X}_s$. If all the concentrations in arbitrary units are multiplied by 5×10^{-6}, the value of $\bar{X}_s$ comes out properly. The values of the concentration of pollution thus computed are shown in the last column of Table I.

Acknowledgment

The work reported herein was supported by funds made available by the

* In commenting on the manuscript of this paper, A. C. Redfield pointed out to the author that some of these conclusions have already been deduced numerically for the special case of the Raritan River. These results were obtained using Ketchum's analysis in the course of consultation over the placement of the outfall sewer, but were not published.

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References

1. Ketchum, B. H., "The Flushing of Tidal Estuaries." THIS JOURNAL, **23**, 2, 198 (Feb., 1951).
2. Arons, A. B., and Stommel, H., "A Mixing-Length Theory of Tidal Flushing." *Trans. Amer. Geophysical Union*, **32**, 419 (1951).
3. Pritchard, D., "Estuarine Hydrography." Recent Advances in Geophysics, 1 (1952).
4. Bassindale, R., "Studies on the Biology of the Bristol Channel. II. The Physical Environment and Intertidal Fauna of the Southern Shores of the Bristol Channel and Severn Estuary." *Jour. Ecology*, **31**, 1 (1943).

CLEAN WATERS LITERATURE AVAILABLE

A kit of materials to aid community leaders in their efforts to solve local water pollution problems has been made available by the U. S. Public Health Service. The kit is intended as basic material for local educational efforts concerning the need for pollution control. To augment the kit and tie in local with regional pollution problems, the USPHS also has made available pamphlet condensations of the various detailed basin reports published during the past few years.

Included in the "Let's Have Clean Water" kit are such publications as the following:

"The Fight to Save America's Waters," a Mark Trail "comic book" on public health and conservation.

"Clean Water Is Everybody's Business," a pictorial presentation of pollution control programs.

"Water Pollution in the United States," a summary presentation of the pollution abatement needs of the country.

"The Living Waters," a series of six background readings on the uses of water and the importance of pollution control.

"Chairman's Guide," a series of program suggestions and advice on sources of information for community leaders.

Copies of the "Clean Waters" kit (designated as "Public Health Service Publication No. 264") may be procured at $1.25 per kit from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Condensations of the summary reports for the various drainage basins are avilable from the same source at $0.05 each.

POLLUTION STUDY OF THE RED CLAY CREEK DRAINAGE BASIN

II. Determination of Existing Stream Conditions

By A. Joel Kaplovsky and Jay L. Harmic

Respectively, Supervising Engineer, Delaware Water Pollution Commission, and Biologist, Delaware Game and Fish Commission, Dover, Del.

Based on an extensive survey of the Conestoga basin, Lancaster County, Pennsylvania, a biological measure of stream conditions was proposed by Patrick (3). The results of this study indicated that under healthy stream conditions a great many species representing the various taxonomic groups should be present, but no species should be represented by a great number of individuals. It was also concluded that a pollutant would eliminate many species and the few which did survive would have less competition and more chance for multiplication. More severe toxic effects would result in the complete elimination of some groups and a reduction of specie numbers in other groups. This proposed grouping by Patrick was applied to studies performed within the Red Clay Creek drainage basin (1)(2).

Briefly, the Patrick procedure requires the study or enumeration of the following organisms within a specified stream area:

1. Blue-green algae.
2. Oligochaetes, leeches, and snails.
3. Protozoa.
4. Diatoms, red algae, and other green algae.
5. Rotifers and tricladid worms.
6. Insects and crustaceans.
7. Fish.

Based upon previously established counts and/or specie numbers, one could surmise whether a stream is healthy, semi-healthy, polluted, or very polluted. It is necessary to have established criteria for comparison so that such classifications can be made. Whether the stream area surveyed is rapid flowing, of less swift current, or consists of pools, is of prime importance. An appropriate method of presenting the results is to prepare a histogram (3) from the previously determined maximum and minimum values within a stream subjected to various degrees of pollution. This comparative baseline is employed for classifying a section of the stream as healthy, semi-healthy, polluted, or very polluted.

The biological phase of the stream investigation was scheduled to coincide with studies of the chemical, physical, and bacteriological stream conditions.

Methods

Three carefully selected biological sampling stations were established on Red Clay Creek. A heavy source of pollution enters Red Clay Creek at Yorklyn, Del., which is located 9.65 stream-miles above the confluence with White Clay Creek (2). The upstream sampling station was placed 0.65 mi. above this source of fiber mill waste; the second, 6.6 mi. downstream from the Yorklyn waste discharge; and the third, below a small community (Stanton) 9.6 stream-miles downstream from the fiber mill waste discharge. Both qualitative and quantitative biological observations were made. The initial qualitative work, with the exception of fish seines, was made at the three selected sections or environments. It was found necessary to make a qualitative study prior

to any extensive quantitative study in order to establish or anticipate the range for detailed quantitative measurements. Seining at the selected sampling points proved impractical due to rocky stream bottom. All fish were taken from small impoundments close to the selected sampling stations. No attempt was made to study fish population, merely the number of species.

Quantitative observations were made on two diversified habitats at each station—namely, rapids and pools. Initial qualitative data indicated no significant difference in organisms gathered from the swifter as compared to the organisms found in the less swift waters. Of the several biological sampling series made on Red Clay Creek, only one is reported upon in detail. The upstream station is designated as 10.30, the first downstream station as 3.05, and the furthermost downstream station as 0.5.

The vegetative characteristics within the stream were observed at a distance of approximately one-quarter mile up and downstream (except downstream at station 10.30) at each of the sampling points.

Results

Quantitative biological observations of bottom organisms reported herein were made on June 9, 1952. A typical (1) data sheet compiled for Station

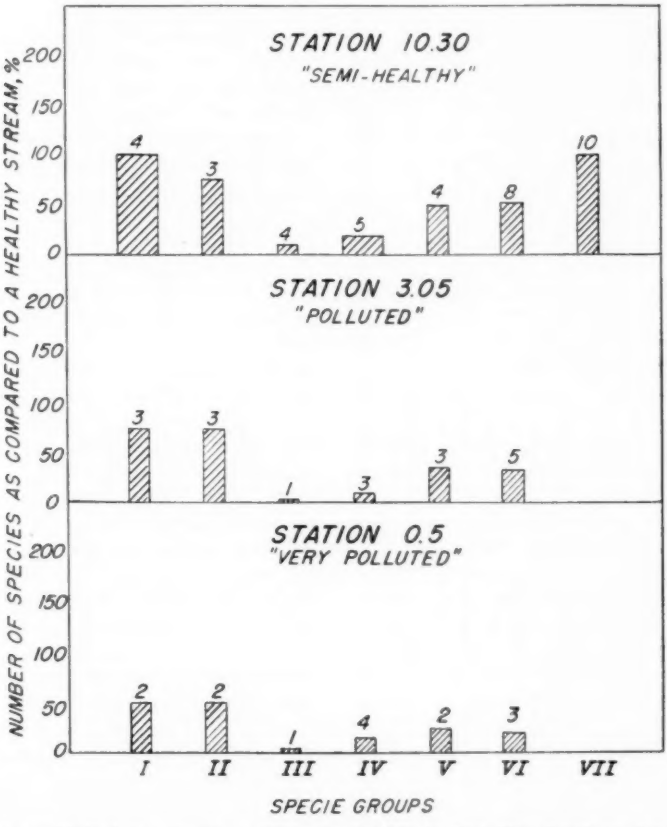

FIGURE 1.—Biological measure of stream conditions in Red Clay Creek on June 9, 1952.

TABLE I.—Biological Measure[1] of Stream Conditions at Station 10.30,[2] Red Clay Creek, on June 9, 1952

I *Cyanophyceae* plus certain *Chlorophyceae*[3]		II Oligochaetes, Leeches, and Pulmonate Snails		III Protozoa		IV *Diatomaceae*, Red Algae, and *Chlorophyceae*		V Rotifers, Clams, Prosobranch Snails, and Tricladid Worms		VI Insects and *Crustacea*		VII Fish
Species	Rel. Density	Species	No. per Sq. Ft.	Species	No. per Liter	Species	No. per Liter	Species	No. per Liter	Species	No. per Sq. Ft.	Species
Oscillatoria	+++	*Placobdella montifera*	12	*Amoeba proteus*	16	*Meridion*	405	*Rotifera* (sp.)[4]	13	*Heptagenia*	33	*Fundulus heteroclitus macrolepidotus*
Rivularia	++	*Glossiphonia complanata*	7	Unidentified species	7	*Tabellaria*	397	*Rotifera* (sp.)[4]	8	*Callibaetis*	17	*Hololepis fusiformis erochrous*
Spirogyra	+	*Lymnaea palustris*	1	Unidentified species	8	*Batrachospermum*	+	*Planaria* (sp.)[4]	17	*Perlidae* (sp.)	2	*Lepomis gibbosus*
Nostoc	+			*Euglena* (sp.)	60	*Ulothrix*	+	*Planaria* (sp.)[4]	33	*Corydalis cornuta*	1	*Lepomis macrochirus macrochirus*
						Zygnema	+			*Chauliodes pectinicornis*	13	*Anguilla bostoniensis*
										Cladoceran (sp.)[4]	15	*Erimyzon oblongus oblongus*
										Cladoceran (sp.)[4]	14	*Rhinichthys atratulus atratulus*
										Streptocephalus seali	5	*Semotilus corporalis*
												Semotilus atromaculatus atromaculatus
												Notropis hudsonius amarus

[1] Based on proposed biological measure of Patrick (3).
[2] Station located immediately above Marshall Bros. vulcanized fiber plant at Yorklyn, Del., and approximately 4 mi. downstream from Kennett Square, Pa.
[3] *Stigeoclonium*, *Spirogyra*, and *Tribonema;* also the bdelloid rotifers plus *Cephalodella megalocephala* and *Proales decipiens*.
[4] Individual identification not made.

10.30 is presented in Table I, and a summation of the findings at each location is presented in the form of a histogram in Figure 1, which shows diagrammatically that Station 10.30 can be designated as semi-healthy, Station 3.05 as polluted, and Station 0.5 as very polluted.

At the upstream sampling point (Station 10.30) the indication of some tributary pollution was emphasized by a marked increase of Column I and the double width of Column IV. The predominance of these two groups indicates a disrupted biological balance influenced, in all probability, by the waste discharges from upstream sources. This pollution is approximately 4 stream-miles distant from the upper sampling location and consists of municipal trickling filter effluent, small slaughterhouse wastes, and surface drainage received from the numerous mushroom establishments. The stream is able to stabilize the pollution to a considerable degree; but biologically speaking, a small residual effect is still evident at Station 10.30.

A short distance downstream from Station 10.30 the heavy discharge of industrial waste enters Red Clay Creek from the two fiber mills situated in Yorklyn, Del. The pollutional effect was quite apparent, as indicated by the biological measures at Station 3.05, 6.6 mi. below the mills.

Station 0.5 showed some additional pollution. This observation conceivably may be attributed to the waste discharges, domestic and industrial, entering Red Clay Creek immediately upstream from this location. No fish could be gathered, after intensive seining of adjacent impoundments, at either Station 3.05 or Station 0.5.

The chemical, physical, and bacteriological analyses of water quality at Station 10.30 conducted on a 24-hr. composite sample gathered on June 11, 1952, were reported previously (2). Indications that this station had been subjected to waste discharges were evident from the *E. coli* content, which averaged 17,000 per 100 ml. The nitrate-nitrogen (2.34 p.p.m.) and traces of ammonia may also be taken as indicative of recent and stabilized pollution.

Discussion

Applying the proposed biological measure of Patrick (3) to several sampling stations within the Red Clay Creek drainage basin proved to be of particular interest. Several qualitative and quantitative studies were needed to establish the baseline within the stream prior to making final quantitative measurements. Although the biological measure procedure is a relatively lengthy one and may prove impractical under certain conditions, it did bring out one significant point. Closer observation of Station 10.30, which was upstream from the major source of pollution tributary to Red Clay Creek, would indicate from the sanitary analyses that the stream was quite satisfactory and contained little or no pollution. The disrupted biological balance indicated pollution had occurred previously. Only after careful scrutiny of the chemical and physical analyses can one note a small amount of pollution reaching Station 10.30. It appears evident that the utilization of biological measures is a more sensitive procedure to use in streams that have received small amounts of pollution, specifically pollution which has come and gone. Downstream from the heavy waste discharge at Yorklyn the biological indices showed complete disruption of the stream balance, as the stream was heavily polluted. The prevailing conditions below the mills were such that studies of toxicity, chemical, physical, or bacteriological measurements could indicate, conclusively and far more quickly than the biological measure technique, that the stream is extensively polluted. Utilization of Patrick's biological measure, due to its sensitivity, would appear

particularly useful in streams receiving small amounts of pollution, whereas other waste measuring techniques would appear more feasible for streams receiving heavier pollution.

Summary and Conclusions

A biological survey was made of the Red Clay Creek drainage basin on the basis of the proposed biological measure of Patrick. Several sampling stations were classified according to the proposed biological measure.

Conclusions reached as a result of the survey are as follows:

1. A biological measure of stream conditions can indicate previous pollution.

2. The biological measure is a more sensitive indicator of pollution than the normal chemical and physical analyses employed.

References

1. Kaplovsky, A. J., "A Comprehensive Study of Pollution and Its Effect Upon the Waters Within the Red Clay Creek Drainage Basin." Del. Water Poll. Comm. (Sept. 19, 1952).
2. Kaplovsky, A. J., Mandel, H., Camper, H. F., and Murphy, J. D., "Pollution Study of the Red Clay Creek Drainage Basin. I. Estimation of Stream Flow Time and Self-Purification." THIS JOURNAL, **25**, 8, 963 (Aug., 1953).
3. Patrick, R., "A Proposed Biological Measure of Stream Conditions, Based on a Survey of the Conestoga Basin, Lancaster County, Penna." *Proc.*, Acad. of Nat. Sciences of Philadelphia, **101**, 271 (1949).

MAKE YOUR HOTEL RESERVATIONS FOR THE FSIWA TWENTY-SIXTH ANNUAL MEETING

The Bayfront Park Auditorium at Miami, Florida, will be the headquarters for the Federation's Twenty-Sixth Annual Meeting, to be held October 13-16, 1953. An outstanding technical and social program is being planned for the four-day meeting.

Requests for room reservations should be addressed directly to the FSIWA Housing Committee, 320 N. Fifth St., Miami, Fla. (see page 1125 for details). It should be noted that the technical program will open on Tuesday morning, October 13, and will close at noon on Friday, October 16, but early arrivals may register on October 12.

WRITE NOW FOR YOUR RESERVATIONS!

Research Survey

SURVEY OF RESEARCH FACILITIES AND PROJECTS—1953

By H. Heukelekian and W. H. Wisely

Chairman, Research Committee, and Executive Secretary-Editor, respectively, FSIWA

To assess the status of the available physical facilities and personnel, and of research projects under investigation in various U. S. institutions on subjects dealing with the treatment and disposal of sewage and industrial wastes, and water pollution, a joint project was undertaken by the headquarters office of the Federation and the Chairman of the Research Committee. The mailing list for the questionnaire was prepared on the basis of the "Review of Current Research and Directory of Member Institutions," published in 1951 by the Engineering College Research Council, American Society for Engineering Education.

Replies were received from 74 of the 108 questionnaires sent out. Despite the high percentage of returns, the canvass cannot be considered complete, as it leaves out the research facilities and projects by State Health Departments, inter- and intra-state agencies, industries, equipment manufacturers, municipal plants, trade associations, and others. It is planned at some future date to complete the survey with additional information from these non-educational and research institutions. In addition, a survey also is contemplated of the projects needing investigation.

The results of the survey of the research personnel and physical facilities available are presented in Table I.

Of the 74 institutions responding to the questionnaire, 18 had physical facilities but no personnel, whereas only 1 had personnel and no facilities, indicating that for some reason personnel is a greater limitation in research than are physical facilities. Only 4 had neither facilities nor personnel, but it is reasonable to assume that of the 34 failing to respond the majority fall in the same category.

In regard to the number of personnel, including part-time and full-time staff members and graduate students, some of the institutions have apparently reported the total number engaged in over-all research activities not necessarily limited to the field of sanitation, giving total numbers of personnel greater than could possibly be available for research in this field. Of the 51 institutions with personnel, possibly 19 fall in this category. Excluding these questionable ones, the numbers vary from 1 to 24 persons engaged in research in various institutions and one with 116 for a conservative estimate of a total of 343 and an average of 11 per institution.

Of the 69 institutions with some kind of physical facility, 66 had chemical laboratory, 58 bacteriological laboratory, 53 hydraulic laboratory, 25 radioactivity facilities, 29 pilot plant, and 21 full-scale plant facilities.

Projects under Study

Active projects were in progress at 36 institutions. Since there were 51 institutions with both personnel and physical facilities, the question arises as to why 15 of the institutions had no active projects. This might be at-

TABLE I.—Survey of Research Personnel and Physical Facilities in U. S. Institutions and Foundations

Institution		Personnel Engaged in Research					Facilities Available						
		Staff Members		Grad. Stud.		Total							
Name	Location	Part-Time	Full-Time	Part-Time	Full-Time		Chem. Lab.	Bact. Lab.	Hydr. Lab.	Radio-active Lab.	Pilot Plant	Full-Scale Plant	Others
1. Univ. of Alabama[1]	Birmingham, Ala.	1	—	—	—	1	+	—	+	—	+	—	—
2. Alabama Poly. Inst.[2]	Auburn, Ala.	—	—	—	—	—	+	—	+	—	—	+	—
3. Univ. of Arkansas[1]	Fayetteville, Ark.	1	2	—	—	3	+	+	+	—	—	—	—
4. Bucknell Univ.	Lewisburg, Pa.	—	—	—	—	—	—	—	—	—	—	—	—
5. Univ. of California	Berkeley, Calif.	5	14	5	—	24	+	+	+	+	+	—	—
6. Univ. of South. Calif.	Los Angeles, Calif.	1	2	2	—	5	+	+	+	+	—	+	—
7. U. Cal. at Los Angeles	Los Angeles, Calif.	3	2	—	—	5	+	+	+	—	—	—	—
8. Calif. Inst. Tech.	Pasadena, Calif.	—	—	—	—	—	+	+	+	+	—	+	—
9. Case Inst. Tech.	Cleveland, Ohio	2	—	2	—	4	+	+	+	+	—	—	—
10. Clemson College	Clemson, S. C.	11	1	5	—	17	+	+	+	—	—	—	—
11. Univ. of Colorado	Boulder, Col.	55	12	72	—	139	+	+	+	+	+	+	—
12. Col. A. and M. College	Ft. Collins, Col.	7	2	6	0	15	+	+	+	—	—	—	—
13. Dartmouth College	Hanover, N. H.	—	—	—	—	—	+	+	+	—	—	—	—
14. Univ. of Denver[3]	Denver, Col.	12	112	—	2	126	+	—	—	—	—	—	—
15. Univ. of Detroit[4]	Detroit, Mich.	25	—	—	—	25	+	+	+	+	+	—	+[5]
16. Univ. of Florida	Gainesville, Fla.	6	5	3	—	14	+	+	—	—	+	+	—
17. Harvard Univ.	Cambridge, Mass.	5	—	2	11	18	+	+	+	+	—	—	—
18. Univ. of Illinois	Urbana, Ill.	3	2	10	—	15	+	+	+	+	+	—	—
19. Illinois Inst. Tech.	Chicago, Ill.	—	—	—	—	—	+	+	+	+	—	—	—
20. State Univ. of Iowa	Iowa City, Iowa	3	—	5	—	8	+	+	+	—	+	+	—
21. Iowa State College[1]	Ames, Iowa	34	6	17	5	62	—	—	—	—	+	—	—
22. Johns Hopkins Univ.	Baltimore, Md.	4	—	—	—	4	+	+	+	+	+	—	—
23. Kansas State College	Manhattan, Kans.	—	—	—	—	—	+	+	+	—	—	—	—
24. Univ. of Kentucky	Lexington, Ky.	—	—	—	—	—	+	+	+	—	—	+	—

[1] Engineering Experiment Station.
[2] Department of Civil Engineering.
[3] Denver Research Institute.
[4] Engineering Research Council.
[5] Ion exchange.

TABLE I.—*Continued*

Institution		Personnel Engaged in Research					Facilities Available						
		Staff Members		Grad. Stud.		Total							
Name	Location	Part-Time	Full-Time	Part-Time	Full-Time		Chem. Lab.	Bact. Lab.	Hydr. Lab.	Radio-active Lab.	Pilot Plant	Full-Scale Plant	Others
25. Kettering Lab.[6]	Cincinnati, Ohio	—	56	—	—	56	+	—	—	+	—	—	+[7]
26. Lehigh Univ.[8]	Bethlehem, Pa.	120	6	90	4	220	+	+	+	—	—	—	—
27. Univ. of Louisville[8]	Louisville, Ky.	8	2	—	11	21	+	+	+	—	+	—	—
28. Univ. of Maine	Orono, Me.	—	—	—	—	—	+	+	+	—	—	—	—
29. Mass. Inst. Tech.	Cambridge, Mass.	4	—	16	—	20	+	+	+	+	+	—	—
30. Mellon Institute	Pittsburgh, Pa.	—	3	—	—	3	+	+	—	—	+	+	—
31. Michigan Inst. Tech.	Houghton, Mich.	—	—	—	—	—	+	+	—	—	—	—	—
32. Michigan State College	East Lansing, Mich.	—	—	—	—	—	+	+	+	+	+	+	—
33. Univ. of Michigan	Ann Arbor, Mich.	2	—	5	—	7	+	+	+	—	+	—	—
34. Miss. State College	State College, Miss.	1	—	1	—	2	+	+	+	—	—	+	—
35. Montana State College	Bozeman, Mont.	3	—	10	—	13	+	+	+	—	—	—	—
36. Nat. Canner's Assn.	Washington, D. C.	—	2	1	—	3	+	+	—	—	+	+	—
37. Univ. of Nebraska	Lincoln, Nebr.	1	—	—	—	1	—	—	—	—	—	+	—
38. Univ. of New Hampshire	Durham, N. H.	—	—	—	—	—	+	+	+	—	—	—	—
39. N. Y. State Coll. of Ceramics	Alfred, N. Y.	10	20	5	—	35	+	—	—	+	—	—	—
40. N. C. State College	Raleigh, N. C.	—	2	1	1	4	+	+	+	+	+	—	—
41. Univ. of N. Carolina	Chapel Hill, N. C.	2	—	1	—	3	+	+	—	—	+	+	+
42. Univ. of North Dakota	Grand Forks, N. Dak.	2	—	—	—	2	+	+	+	+	—	—	—
43. Northeastern Univ.	Boston, Mass.	—	—	—	—	—	+	+	—	—	—	—	—
44. Northwestern Tech. Inst.	Evanston, Ill.	1	—	—	—	1	+	+	+	—	—	+	—
45. Notre Dame Univ.	South Bend, Ind.	—	—	—	—	—	+	+	+	+	—	—	—
46. Ohio State Univ.	Columbus, Ohio	—	2	4	—	6	+	+	+	—	+	+	—
47. Univ. of Oklahoma[9]	Norman, Okla.	1	—	5	—	6	+	+	+	+	+	+	+
48. Oregon State College	Corvallis, Ore.	19	3	8	—	30	+	+	+	+	+	—	—
49. Penn. State College	State College, Pa.	3	—	12	—	15	—	—	—	—	—	—	—
50. Univ. of Pittsburgh	Pittsburgh, Pa.	—	—	—	—	—	+	—	+	—	—	—	—

[6] College of Medicine, University of Cincinnati.
[7] Toxicological laboratory.
[8] Institute of Research.

TABLE I.—*Continued*

Institution		Personnel Engaged in Research					Facilities Available						
		Staff Members		Grad. Stud.		Total							
Name	Location	Part-Time	Full-Time	Part-Time	Full-Time		Chem. Lab.	Bact. Lab.	Hydr. Lab.	Radio-active Lab.	Pilot Plant	Full-Scale Plant	Others
51. Princeton Univ.	Princeton, N. J.	—	—	—	—	—	—	—	—	—	—	—	—
52. Pub. Health Serv. (U. S.)	Cincinnati, Ohio	15	101	—	—	116	+	+	—	+	+	—	+
53. Purdue Univ.	Lafayette, Ind.	2	—	5	—	7	+	+	+	—	+	+	—
54. Univ. of Rhode Island	Kingston, R. I.	1	1	2	—	4	+	+	+	—	+	+	—
55. Univ. of Rochester	Rochester, N. Y.	135	100	50	150	435	+	+	+	+	—	—	—
56. Rutgers Univ.[9]	New Brunswick, N. J.	—	—	—	—	—	—	—	+	—	—	—	—
57. Rutgers Univ.[10]	New Brunswick, N. J.	3	2	10	—	15	+	+	—	—	+	+	—
58 S. Dak. School of Mines and Tech.	Rapid City, S. Dak.	1	1	—	—	2	+	—	+	—	—	—	—
59. Stanford Univ.	Stanford, Calif.	—	—	—	—	—	—	—	—	—	—	—	—
60. Stanford Res. Inst.	Stanford, Calif.	40	550	—	—	590	+	+	—	+	+	—	—
61. Stevens Inst. Tech.	Hoboken, N. J.	—	—	—	—	—	+	—	+	—	—	—	—
62. Swarthmore College	Swarthmore, Pa.	—	—	—	—	—	+	+	+	—	—	—	—
63. Syracuse Univ.[8]	E. Syracuse, N. Y.	100	30	50	100	280	+	+	—	+	—	—	—
64. Univ. of Tennessee	Knoxville, Tenn.	—	—	—	—	—	+	+	+	—	—	—	—
65. Univ. of Texas	Austin, Tex.	3	1	4	—	8	+	+	+	—	—	—	—
66. Texas A. & M. Res. Found.	College Station, Tex.	45	1	24	—	70	+	+	+	—	+	+	+
67. Texas Eng. Exp. Sta.	College Station, Tex.	40	40	40	—	120	+	+	—	—	+	+	—
68. Texas Tech. College	Lubbock, Tex.	—	—	—	—	—	+	+	+	—	—	—	—
69. Tufts College	Medford, Mass.	—	—	—	—	—	+	+	+	—	—	—	—
70. Utah State Agr. Coll.	Logan, Utah	—	—	—	—	—	—	—	—	—	—	—	—
71. Utah Eng. Exp. Sta.	Salt Lake City, Utah	1	—	2	—	3	+	+	+	+	—	—	—
72. St. Coll. of Washington	Pullman, Wash.	2	1	2	—	5	+	+	+	+	+	—	—
73. West Virginia Univ.[1]	Morgantown, W. Va.	5	17	13	—	35	+	+	+	—	—	—	—
74. Univ. of Wisconsin	Madison, Wis.	3	1	8	1	13	+	+	+	—	+	—	—

[9] College of Engineering.

[10] New Jersey Agricultural Experiment Station.

TABLE II.—Survey of Active Projects Under Way and Planned in Various U. S. Institutions and Foundations

No.	Institution Name	Project Supervisor	Project Description	Date		Sponsor
				Start	Term.	
5	Univ. of California	H. B. Gotaas and others	1. Underground water pollution	1951	1954	Calif. Water Poll. Con. Bd.
		G. T. Orlob and R. G. Butler	2. Reclamation of polluted water by spreading	1952	1953	
		H. B. Gotaas and others	3. Removal of radioisotopes by sewage treatment	1951	—	A.E.C.
		T. R. Simpson and others	4. Salt-water intrusion into ground aquifers	1952	1953	
		H. B. Gotaas and others	5. Algae symbiosis	1950	—	N.I.H.
		P. H. McGauhey and others	6. Composting of municipal refuse	—	—	—
		E. Q. Moulton	7. Reclamation of fresh water from sea water by use of membranes and by distillation	—	—	Dept. of Army
6	Univ. of S. Calif.	R. C. Merz and others	1. Pollution of ground waters through leaching from dumps	1951	1954	Calif. Water Poll. Con. Bd.
7	U. of Calif. at Los Angeles	A. F. Bush	1. Waste-water reclamation and utilization	—	—	Calif. Water Poll. Con. Bd.
			2. Use of waste water to control salt-water intrusion	—	—	—
8	Calif. Inst. of Tech.	J. E. McKee	1. Literature survey of water quality criteria	—	—	Calif. Water Poll. Con. Bd.
		A. Goetz	2. Molecular membrane filters for bacteriological and chemical analyses	—	—	—
9	Case Inst. of Tech.	G. E. Barnes	1. Development of synthetic sewage	—	—	—
			2. Determination of tolerance limits for biochemical treatment of industrial wastes	—	—	—
			3. Measurement of flow by tracer technique	—	—	—

TABLE II.—*Continued*

No.	Institution Name	Project Supervisor	Project Description	Date		Sponsor
				Start	Term.	
11	Univ. of Colorado	R. E. Leffel	1. Sewage treatment by flocculation	—	—	N.I.H.
15	Univ. of Detroit	Dr. McCormack	1. Recovery of metal ions from dilute solutions by ion exchange	1951	1953	—
		Dr. McCormack	2. Recovery of chromate by liquid-liquid extraction	1951	1953	—
		Dr. McCormack	3. Removal of iron from pickling baths with recovery of iron as ferric chloride and of acid	1952	1953	—
			4. Recovery of acid and metal salts by pickling baths using immiscible solvents	1953	1953	—
16	Univ. of Florida	J. E. Kiker	1. Subsurface sewage disposal	1948	Indef.	—
		J. E. Kiker	2. Diatomaceous earth filters	1948	Indef.	—
		T. Jaffe	3. High-rate chemical and biological treatment of sewage	1950	1954	—
		W. T. Calaway	4. Biology and ecology of sewage filtration	1950	1954	N.I.H.
		E. R. Hendrickson	5. Rapid determination of sewage strength in terms of B.O.D.	1951	1954	—
		T. Furman	6. Anti-pollution and sewage disposal for Florida communities	1951	Indef.	Winn-Lovett Grocery Co.
		E. B. Phelps	7. Stream sanitation in Florida	1951	1953	Fla. St. Bd. of Health
		D. B. Smith	8. Synthetic sewage standardization	1952	Indef.	—
		J. B. Lackey	9. Utilization of sewage plant effluents for the growth of algae suitable for animal feed	1953	1955	—
		J. B. Lackey	10. Quantity and quality of inshore, estuarine, and neritic algae and protozoan plankton	1953	1954	—
		J. B. Lackey	11. Incidence and causes of marine blooms of the "red tide" type	1953	Indef.	—

TABLE II.—*Continued*

No.	Institution Name	Project Supervisor	Project Description	Date		Sponsor
				Start	Term.	
		T. Furman	12. Effects of polyelectrolytes on sewage filterability	1953	1955	—
		T. Jaffe	13. Removal of solid matter from sewage by air flotation	1953	1955	F. S. Gibbs, Inc.
17	Harvard Univ.	E. W. Moore	1. Precision of polarography in water and waste	1952	1953	—
		J. C. Morris	2. Breakpoint studies on chlorinated glycine	1952	1953	Wallace & Tiernan Co.
		J. C. Morris	3. Equilibria of ammonia-chloramines	1952	1953	—
		H. A. Thomas	4. Studies on dispersal of radioactivity in natural bodies of water	1950	Indef.	A.E.C.
		J. C. Morris	5. Studies on equilibria of ion exchange resins as related to chemical warfare agents	1950	1953	U. S. Army
		S. L. Chang	6. Survival of amoebic cysts at low temperatures	1952	Indef.	U. S. Army
		E. W. Moore	7. Purification of water by flotation with quaternary ammonium compounds	1952	1953	U. S. Army
18	Univ. of Illinois	H. E. Babbitt	1. Operation of erdlators and diatomaceous earth filters for purification of polluted waters	1947	1954	U. S. Eng. Corps
		H. E. Babbitt	2. Effect of and concentration of radioactive isotopes in anaerobic digestion of sewage sludges	1952	1954	A.E.C.
20	State Univ. of Iowa	—	1. Activated silica as a coagulant aid in Iowa River water	—	—	—
			2. Correlation of M.P.N. turbidity and flow in Iowa River water	—	—	—

TABLE II.—*Continued*

No.	Institution Name	Project Supervisor	Project Description	Date		Sponsor
				Start	Term.	
			3. Pretreatment of feathers to increase their rate of anaerobic digestion	—	—	—
			4. Percolation of subnatant from digested sludge through various subsoils	—	—	—
22	Johns Hopkins Univ.	C. E. Renn	1. Circulation patterns in Chesapeake Bay	1951	—	Md., Va., and Off. Naval Res.
		C. E. Renn	2. Treatability of dye plant wastes	1952	1953	American Cyanamid Co.
		Talboys	3. Treatment of radioactive laundry wastes	1952	1954	A.E.C.
		C. E. Renn	4. Disposal of radioactive wastes at sea	1953	1954	A.E.C.
25	Kettering Lab.	—	1. Establishment of toxicological limits and standards for chemicals present in industrial wastes from the hygienic standpoint	—	—	—
26	Lehigh Univ.	—	1. Analytical methods for metal waste	—	—	—
29	Mass. Inst. Tech.	R. Eliassen	1. Methods of B.O.D. analysis	—	—	N.I.H.
			2. Effect of synthetic detergents on aerobic treatment	—	—	N.I.H.
			3. Effect of radioactive materials on deoxygenation rates in receiving waters	—	—	A.E.C.
30	Mellon Inst.	E. W. Tillotson	1. Permselective electrolysis of $FeSO_4 + (NH_4)_2SO_4$	1952	Indef.	—
			2. Persistence of phenolic substances in water	1953	Indef.	—

TABLE II.—*Continued*

No.	Institution Name	Project Supervisor	Project Description	Date		Sponsor
				Start	Term.	
			3. Production of phenolic substances by microorganisms	1953	Indef.	—
			4. Pickle liquor coke oven ammonia process	1947	Indef.	—
			5. Bibliographic survey of toxicity	1952	Indef.	—
32	Michigan St. Coll.	—	1. Flotation of sewage solids	—	—	—
			2. High-speed garbage disposal	—	—	—
			3. Effect of cyanides on trickling filters	—	—	—
33	Univ. of Michigan	J. A. Borchardt	1. Anaerobic fermentations of milk wastes	1953	—	—
			2. Development of toxicological techniques for evaluation of industrial pollutant	1953	—	—
			3. Use of oxidation-reduction potentials in sludge digestion	—	—	—
36	Nat. Canners Assn.	N. H. Sanborn	1. Aeration of cannery wastes	—	—	—
			2. Digestion of cannery wastes	—	—	—
			3. Odor control of lagooned cannery wastes	—	—	—
40	N. C. St. College	C. Smallwood	1. Mechanism of adsorption by activated sludge	1952	1953	N.I.H.
		N. Nemerow	2. Cotton kier waste treatment	1952	1953	—
		N. Nemerow	3. Textile dye wastes	—	—	—
		N. Nemerow	4. Municipal and textile dye wastes	—	—	—
		N. Nemerow	5. Disposal of wastes from paper and pulp industry	—	—	—

TABLE II.—*Continued*

No.	Institution Name	Project Supervisor	Project Description	Date		Sponsor
				Start	Term.	
		N. Nemerow	6. A study of the mechanism of biochemical oxidation of solutions and colloidal suspensions of organic matter	—	—	—
		N. Nemerow	7. Effect of chlorine on sewage bacteria in the presence of textile wastes	—	—	—
41	Univ. of N. Carolina	D. A. Okun	1. Effect of D.O. concentration on biochemical activity in sewage treatment	1953	1954	N.I.H.
42	Univ. of N. Dakota	A. M. Cooley	1. A study of the nature and amounts of wastes from potato flour plants	—	—	—
		A. M. Cooley	2. Influence of phenolic materials from lignite carbonization on the microorganisms of anaerobic digesters	—	—	—
46	Ohio State Univ.	W. D. Sheets	1. Toxic effect of plating wastes on biological processes and on fish	—	—	N.I.H., Ohio Dept. Health, Ohio Dept. Nat. Res., Orsanco, Republic Steel
		W. D. Sheets	2. Chemical and biological methods for the treatment of phenolic wastes from petroleum refinery	—	—	—
47	Univ. of Oklahoma	G. W. Reid	1. Effects of enzymatic on sludge digestion	—	—	—
		G. W. Reid	2. Effect of nitrogen forms on algae production	—	—	—
		G. W. Reid	3. Effect of Chloroben on K values	—	—	—
		G. W. Reid	4. Effect of density, age, population, etc., of sewage slime on k values	—	—	—

TABLE II.—*Continued*

No.	Institution Name	Project Supervisor	Project Description	Date		Sponsor
				Start	Term.	
48	Oregon State Coll.	—	1. Investigation on sulfite waste liquor	—	—	Nat. Council for Stream Improv.
52	U. S. Pub. Health Serv.	R. C. Palange and others	1. Studies of the effects of radioactive wastes on streams	—	—	—
		L. R. Setter and others	2. Development of radioactive waste treatment processes	—	—	—
		P. W. Kabler and others	3. Bacteriological and biochemical techniques for rapid detection of bacteria	—	—	—
		J. W. Riddle and N. A. Clarke	4. Studies on the role of viruses in environmental health	—	—	—
		W. B. Cooke	5. Occurrence, activity, and fate of fungi in water and water purification	—	—	—
		C. W. Chambers	6. Efficiency of germicidal agents in sanitary practice	—	—	—
		C. M. Palmer	7. Control of biological growths and algae blooms in surface water and water impoundments	—	—	—
		C. M. Tarzwell and A. R. Gaufin	8. Stream ecology and its relationship to water pollution	—	—	—
		P. Doudoroff and M. Katz	9. Fish physiology and toxicology related to industrial waste pollution	—	—	—
		C. C. Ruchhoft and W. A. Moore	10. Development of chemical analytical techniques for environmental health and water pollution control	—	—	—
		F. J. Ludzack	11. Destruction of organic chemicals by microorganisms	—	—	—
		F. M. Middleton and others	12. Chemistry of tastes and odors in water caused by industrial pollution	—	—	—
		H. Levine	13. Kinetics of chemical reactions of importance in sanitation	—	—	—

TABLE II.—*Continued*

No.	Institution Name	Project Supervisor	Project Description	Date		Sponsor
				Start	Term.	
		J. S. Nader	14. Development of physical instrumentation for measurement and control of environmental parameters	—	—	—
		H. Black and others	15. Industrial waste studies	—	—	—
		R. S. Smith and S. Soneda	16. Sewage and waste treatment studies	—	—	—
		C. B. Kelly and W. Arcisz	17. Shellfish sanitation studies	—	—	—
53	Purdue Univ.	D. E. Bloodgood	1. Development of household incinerators for sewage and garbage	—	—	—
		D. E. Bloodgood	2. Character and treatment of strawboard wastes by anaerobic process	1948	—	Nat. Council for Stream Improv.
		D. E. Bloodgood	3. Treatment of dairy wastes	—	—	—
		D. E. Bloodgood	4. Treatment of brewery wastes—disposal of spent grain, press liquors, and spent hops	—	—	—
			5. Disposal of wastes from food canning plants by anaerobic digestion	—	—	Nat. Canners Assn.
		D. E. Bloodgood	6. Disposal of cyanide and other toxic wastes	—	—	—
		D. E. Bloodgood	7. Fundamentals of sedimentation	—	—	—
		D. E. Bloodgood	8. Aerobic disposal of household wastes	—	—	—
54	Univ. of Rhode Island	H. Campbell	1. Study of cotton finishing wastes	—	—	N. E. Interstate Water Poll. Con. Comm.; Bradford Dyeing Assn.
57	Rutgers University[1]	J. Balmat	1. Colloids in sewage	1950	1955	—
		R. Manganelli	2. Effect of detergents on sewage treatment processes	1949	1953	—
		H. Heukelekian and others	3. Mechanism of anaerobic digestion	1947	1953	N.I.H.

[1] New Jersey Agricultural Experiment Station.

TABLE II.—*Continued*

No.	Institution Name	Project Supervisor	Project Description	Date		Sponsor
				Start	Term.	
		H. Heukelekian and others	4. Trickling filtration	1947	1954	—
		H. Heukelekian and others	5. Sulfur transformation and effect of sulfur compounds on sewage treatment processes	1947	1953	N.I.H.
		H. Heukelekian and others	6. Effect of antibiotics on sewage treatment processes	1953	1955	—
		M. Rand	7. Laboratory investigations on stream reaeration and deoxygenation	1949	1954	—
		H. Orford and others	8. Treatment of cook liquors and white water	1946	Indef.	Nat. Council for Stream Improv.
		H. Orford and others	9. Lime for waste treatment	1946	Indef.	Nat. Lime Ass.
		H. Heukelekian and others	10. Survival of tubercle bacilli	1947	Indef.	N.I.H.
		H. Orford, H. Heukelekian, and others	11. Survey of chemical and bacteriological quality of well waters in New Jersey	—	—	—
		H. Heukelekian and others	12. Analytical methods	—	—	—
		H. Orford and others	13. Rural waste disposal	1951	1953	U.S.D.A.
		H. Heukelekian and others	14. Bacterial treatment of oil containing sulfur compounds	1952	1953	Stand. Oil of N. J.
63	Syracuse Univ.	C. S. Grove	1. Mechanism of ozonization	1951	1953	Welsbach Corp.
		E. Reed	2. Bacteriological control of paper mill processes	—	—	Nat. Paperboard Assn.
65	Univ. of Texas	E. W. Steel and E. J. M. Berg	1. Effect of sewage irrigation on soils	1952	1953	N.I.H.
		E. W. Steel and others	2. Use of algae in treatment of radioactive wastes	1952	1954	A.E.C.
		H. E. Hargis	3. Lagooning of dairy wastes	1952	1953	—
66	Texas A. & M. Res. Found.	—	1. Surveys of types and nature of pollution of coastal waters and the effect of pollutants on marine life	—	—	—

TABLE II.—*Continued*

No.	Institution Name	Project Supervisor	Project Description	Date		Sponsor
				Start	Term.	
67	Texas Eng. Exp. Sta.	—	1. Disinfection of rural water supplies	—	—	—
			2. Sewage purification by rock filters	—	—	—
			3. Oxidation of settled sewage by horizontal filters	—	—	—
			4. Sedimentation of sewage	—	—	—
			5. Effect of microflora on the rate of deoxygenation in the standard B.O.D. test	—	—	—
72	St. Coll. of Washington	G. H. Dunstan	1. Microbiology and biochemistry of waste disposal processes	1952	1954	—
		G. V. Leete	2. Studies of the Green Giant cannery and the Dayton sewage treatment plant	1950	1953	—
		G. V. Leete	3. Ground-water contamination from septic tanks and refuse dumps	1953	1955	—
		G. H. Dunstan	4. Cannery waste disposal by irrigation	1953	1953	—
73	West Virginia Univ.	K. L. Temple	1. A study of the nature and causes of acidity in the drainages of some bituminous coal mines	1944	1953	Bituminous Coal Res., Inc.
74	Univ. of Wisconsin	E. H. Bryan	1. Use of biological filters for B.O.D. determination	1952	1954	—
		G. A. Rohlich	2. Studies on treatment of packing plant wastes	1951	1953	Oscar Mayer & Co.
		G. A. Rohlich	3. Air flotation for sewage and industrial waste treatment	1952	1953	—
		M. S. Nichols	4. Use of ion-exchange resins for the tertiary sewage	1952	1954	Wisc. Lake Res. Comm.
		G. A. Rohlich	5. Methods of harvesting algae	1952	1954	F. Daniels
		W. J. Katz and G. A. Rohlich	6. Studies on adsorption by activated sludge	1952	1953	Eng. Exp. Sta.

tributed to lack of time, financial support, or ideas.

There was a total of 148 projects (Table II), with an average of 4 projects per institution, varying from a minimum of 1 to a maximum of 17 projects. The projects show a wide diversification, with surprisingly few duplications. The following tabulation shows a possible breakdown of the projects:

Sewage	40
Industrial wastes	38
Water pollution	19
Methods	14
Reclamation of water	4
Radioactivity	10
Refuse and garbage	2
Standards and water quality criteria	2
Disinfection	7
Biology	4
Toxicity	2
Health	3
Unclassified	3
Total	148

Some of the problems are broad in scope and extend over a considerable number of years, whereas others are more specific.

In 1943, 1944, and 1945, the Research Committee of the Federation compiled a list of problems under investigation then (1)(2)(3). The total number of projects listed for those years compares with that obtained from the present survey as follows:

1943	128
1944	94
1945	82
1953	148

The earlier surveys were made during the World War II period and it is surprising that during the 8-year period since the last survey the number of projects under study has not shown a greater increase. Part of this might be attributed to the method of coverage. The earlier surveys were made with the aid of the Member Association secretaries, whereas the present one was made by sending questionnaires to the various institutions. It is expected that when additional inquiries are sent to the State Health Departments, inter- and intrastate agencies, industries, equipment manufacturers, municipal plants, and trade associations, a more complete coverage will be obtained.

The source of support for the various projects was not completely indicated, but the information available may be broken down as follows:

State and interstate	11
Federal	42
University	23
Industry	17

Federal support comes mainly in the form of grants from the National Institutes of Health and the Atomic Energy Commission, with a few other sources from various governmental agencies. Many of the university funds may actually be regarded as derived from state sources.

References

1. FSIWA Research Committee, "Survey of Sewage Research Projects—1943." *Sewage Works Jour.*, **15**, 3, 466 and 702 (May, 1943).
2. FSIWA Research Committee, "Survey of Research Projects under Investigation and Requiring Study—1944." *Sewage Works Jour.*, **16**, 4, 759 (July, 1944).
3. FSIWA Research Committee, "Survey of Research Projects under Investigation and Requiring Study—1945." *Sewage Works Jour.*, **17**, 4, 770 (July, 1945).

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

OUTFALL SEWER REPAIR AT LITTLE ROCK

BY T. W. CLAPHAM

Manager, Little Rock Sanitary Sewer System, Little Rock, Ark.

During routine cleaning of the Little Rock 60-in. diameter outfall with the sewer hoe, it was observed that the water in the line was becoming deeper and deeper—over hip-boot depth, in fact. Since it was obvious that the water was not running uphill, it seemed logical to suppose that the pipe had settled out of grade. A careful check of the terrain over the pipe line showed a depression about 4 or 5 ft. deep at the location where the pipe was judged to have dropped below grade. This line was laid in 1937 in clayey river sand; according to plans, it was about 21 ft. deep at the flow line.

The normal flow of sewage through this line was to a depth of about 1½ ft. Further investigation (made from inside the sewer) showed that at the suspected drop the pipe was flowing full or under head. This indicated at least a 3½-ft. drop in the line, so that, in effect, a section extending for about 125 ft. was acting as an inverted siphon. As could be expected, this section slowed down the flow to a point where some of the solids were settling out and the capacity of the pipe was being seriously reduced. With this preliminary information, it was decided to attempt to raise this line—while in use—to the original grade.

Because the pipe was laid in a flat area (at the southeast corner of the Municipal Airport) only about 1 mi. from the Arkansas River, and because nearby Fourche River used to overflow a slough within about 100 ft. of where the pipe had sunk, it was feared that quicksand might be encountered. As a result, it was decided to bore test holes at intervals of 50 ft. on each side of the ditch for 300 ft. The holes were staggered so that, in effect, there was a test hole every 25 ft. along the line. The holes were driven to a depth of 25 ft.

Cores showed about 10 ft. of "buckshot," 5 ft. of sand and clay, 5 ft. of moist sand and clay, and 5 ft. of wet sand that contained a trace of clay. There was quite a bit of discussion as to whether or not the water encountered was water that had leaked out of the opened sewer joints, or quicksand caused by a flow of water from nearby Fourche River. It was finally concluded that the water was probably sewage that had escaped from the pipe. Based on the test hole results, it was decided to embark upon the project at once, even though there was a strong probability of winter rains. Because of the drought of the previous year (summer of 1952), it was felt that the water table was probably as low as it would ever be, and that advantage should be taken of this situation.

Plan of Attack

The many unknown factors involved made it evident that no contractor would make a firm bid on the proposed job without bidding so high that the cost would be prohibitive. The Sewer

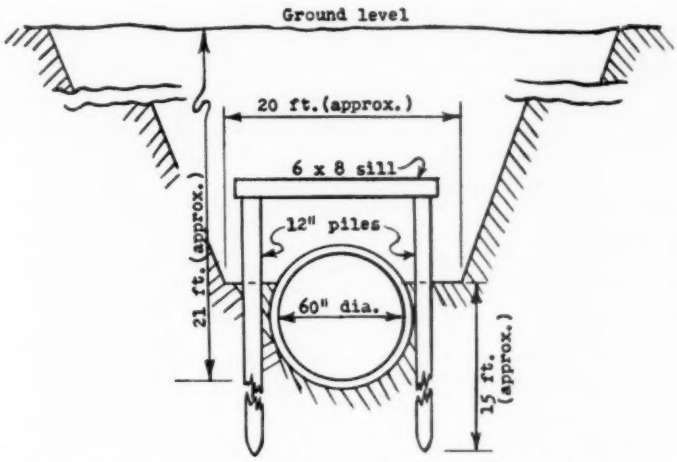

FIGURE 1.—General scheme of ditch excavation and location of pile bents for lifting and stabilizing 60-in. outfall sewer.

Committee, therefore, decided to have a private contractor do the work on a force account basis. Davies and Davies, municipal contractors of Little Rock, were employed, with Kenneth W. Lefever as the supervisory engineer. The plan of operation, as conceived and agreed upon, was to be as follows:

The pipe was to be uncovered so that inspection of actual conditions could be made. The ditch at the level of the top of the pipe was to be about 20 ft. wide, the side slopes from there to the top (ground level) being roughly at the angle of repose of the material. Once the top of the pipe was uncovered, excavation was to be by hand until approximately the top one-third of the pipe was in view. Following this piles were to be driven on each side of the center of the pipe and spaced about 4 ft. apart along the length, or a pile on each side of each section of pipe. The piles were to be driven to sufficient depth to provide a base for lifting and supporting operations.

Once the piles were driven to the required depth (about 15 ft.) they were to be cut off to the correct grade and 6-in. by 8-in. oak caps were to be installed, reaching from one side of the line to the other to form bents (see Figure 1). It was proposed then to excavate as far down the circumference of the pipe as possible and to pass a sling under individual pipe sections. The sling was to pass over a 50-ton hydraulic jack, which was to be sup-

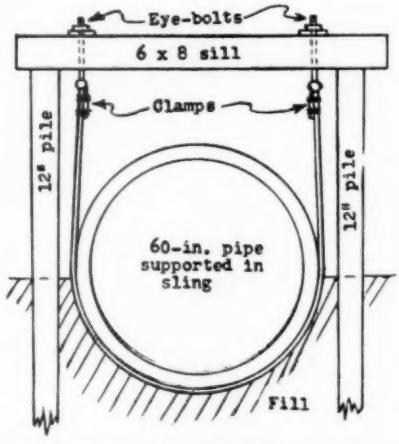

FIGURE 2.—Method of supporting sections of sunken 60-in. outfall sewer after raising to proper grade.

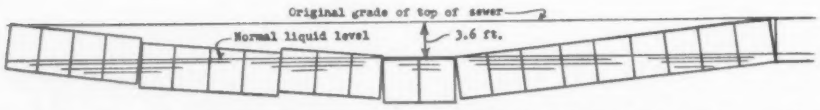

FIGURE 3.—At the worst point, the sewer had sunk 3.6 ft. below original grade, creating an inverted siphon effect and opening many joints.

ported on the sills, so the pipe could be jacked to the proper grade. Following this, galvanized wire rope slings were to be passed under the pipe and fastened to the sills, thus supporting the pipe at the proper grade (see Figure 2).

After the pipe was all hung to grade, it was proposed to build a plug to shut off the sewage for about 3 hr. while the bottom half of each opened joint was sealed from the inside with a hot-poured jointing compound. The sewage was then to be turned back into the line, the joints concreted from the outside, and a supporting concrete mat poured under the pipe. All that would remain was to backfiill.

Ditching Operation

As this job was unique in the Department's experience, it seemed worth while to pass on the actual procedure to others, so that if they should be faced with a similar problem a solution might be suggested.

To start the job, the ditch was dug with a ¾-cu. yd. dragline working the length of the ditch. After the initial ditch was dug to within about 1 ft. of the top of the 60 in. pipe, the dragline worked first on one side of the ditch, and then the other, sloping the sides to a safe angle. Uncovering the pipe involved moving approximately 2,600 cu. yd. of earth. Figures 3 and 4 show the conditions encountered.

FIGURE 4.—Close-up of sunken sewer at worst point.

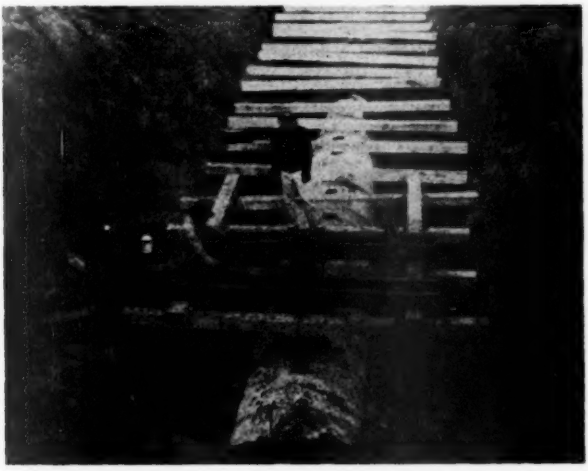

FIGURE 5.—Set-up for initial hoist of first pipe section.

After the ditch was excavated to what was thought to be a safe slope, piles were driven on either side of the pipe as planned. The 12-in. butt, creosoted piles were driven to a depth calculated to give the required bearing on the basis of the *Engineering News-Record* formula

$$P = \frac{2WH}{S + 1}$$

in which P is the safe load in pounds; W is the weight of the hammer in pounds; H is the height of fall in feet; and S is the penetration of the last blow in inches. As a 2,000-lb. hammer was used with a free fall of 20 ft., and the penetration of the final blow was 1 in., substitution in the formula gave a load bearing capacity of 40,000 lb., or 20 tons, per pile. With two piles per pipe section, a load bearing capacity of about 40 tons was provided.

Piles were driven the full length of the ditch and on both sides of the pipe before further work was done, because it was felt that the piles would help to stabilize the open ditch. After the piles were in place, they were cut off 2 ft. above the correct grade of the pipe top and 6-in. by 8-in. oak sills were put in place, being anchored to the piles by steel pins (Figure 5).

Pipe Lift Difficulties

No difficulty had been anticipated in threading a cable under each pipe section for hoisting, but it was discovered that the pipe originally had been laid on heavy timbers, thus presenting an unforeseen difficulty. This method had to be discarded, therefore, and another adopted.

It was next decided to cut a hole in the top of each pipe section so that some kind of hook could be inserted. In accordance with this line of reasoning, a 6-in. square hole was drilled in the top of each pipe. Since the pipe had a double line of 3-in. by 8-in. steel mesh in its 6-in. shell thickness, this was quite a job in itself. It was accomplished by using an air-driven, carbide-tipped rotary drill to make three holes on each side of the square opening. When steel was encountered, a cutting torch was used to remove it. As the result of much labor—and profanity—a hole was made in each of the 30 joints of pipe that it was proposed to raise.

The pipe itself weighed 5,000 lb. per length. Of course, there was also the weight of the sewage in the pipe, plus the suction of the mud and quicksand. It was estimated that 10,000 lb. per

length would have to be lifted if the pipe was to be raised.

A local foundry made the two pipe hooks, and the yokes to fit over the 50-ton jacks. The jack yokes were made of steel channel suitably braced and pinned to take the jack loads and transfer them to the lifting hooks (Figure 6). The lifting hooks were of similar construction, but the center connection (Figures 6 and 7) accommodated a double 1-in. by 5-in. steel strap that fit through the hole drilled in the pipe and had a third 1-in. by 5-in. piece pivoted at its lower end. Thus, the hook could be inserted through the 6-in. square hole with the pivoted piece between the upright straps, the piece turned to a horizontal position inside the pipe, and the entire device lifted to have the crossbar bear on the under side of the crown.

Originally the jack load was transferred from the yoke to the lifting hook by means of a double cable at each side of the jack (Figures 5 and 6). In practice, however, the cables stretched so much under load that they were replaced by two 1-in. by 5-in. steel connecting links (Figure 7). The stiffer arrangement worked much more satisfactorily.

Because of the expected load, other 6 by 8's were placed on top of the caps at right angles to their length to spread the load over several piles and sills. These, in turn,supported two 8-in. steel I-beams to support each jack. This set-up is shown in Figures 5 and 6.

When everything was in place, the first trial was made at lifting. It was decided to start the lift from the upstream end of the line for two reasons: first, to save the bottom bells of the pipe; and secondly, so that the sewage would always be falling into a pipe, and thus not undermine the remaining sections.

The initial attempt to lift the first

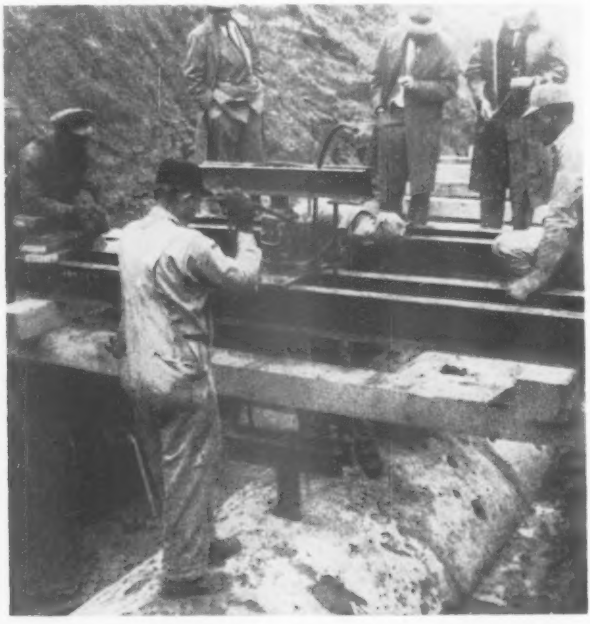

FIGURE 6.—Close-up of initial hoisting rig. Cables were replaced by steel straps in later version.

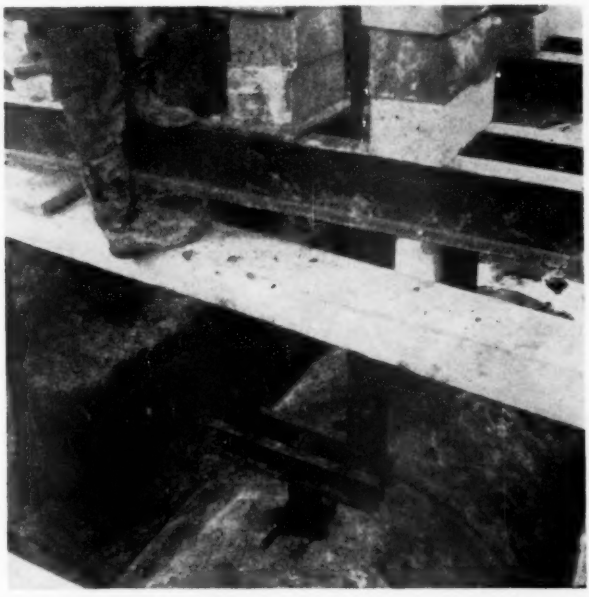

FIGURE 7.—Close-up of pipe lifting hook in 6-in. square hole. Note steel tie bars replacing cables of Figure 6.

pipe section was quite disappointing, as the best effort produced a lift of only about ¾ in. It must be remembered that this first pipe section was fixed at both ends, and that it had to break the initial suction. The lifting effort did produce a crack running along the top of the section from bell to spigot. After trying another pipe, and getting still another crack, a saddle was devised for the hook, so that the load would be distributed over a wide area and not be applied on a single edge. This saddle was simply a couple of pieces of ½-in. iron, 5 in. wide and 18 in. long, that were bent to a curvature slightly less than that of the pipe, or a 60-in. circle. Thus, when pressure was applied the saddle fit snugly against the crown of the pipe, distributing the load and eliminating the tendency to crack.

Once a pipe section was raised to grade, a ½-in. galvanized cable was threaded under it and secured to eye-bolts on either side of the sill (Figures 2 and 8). As there were about 4 in. of thread on each eye-bolt, it was possible to make minor adjustments with the use of a wrench.

The task of threading the cables under the pipe was facilitated by the use of a round-iron needle that was bent to conform with the outside diameter of the pipe. The cable was attached, and this semi-circular needle was threaded under the pipe from one side to the other.

After 10 or 12 pipe sections had been raised to grade, a sleet and ice storm shut down the job. As the sleet gradually melted, the bank on one side of the ditch slid a little. It then became necessary to drive sheeting on both sides of the ditch (just outside of the piles) for a distance of about 50 ft. Once the ditch was stabilized, lifting operations were resumed.

It was found advisable to make the lift in the lowest part of the line (Figure 8) in two stages. Where the pipe was down about 3.6 ft., an initial lift of 2 ft. was made and the apparatus moved to the next pipe, bring-

FIGURE 8.—View at point of worst subsidence shows amount of lift required. Section in immediate foreground was 3.6 ft. below original grade line. Sections in background (upstream) have already been lifted to grade and hung on cable slings. Final lift is in progress on two sections behind one shown after partial lift.

ing the line to grade with a second lift. In the deepest part of the sink, it took approximately 3 cu. yd. of material to fill the void left by each raised pipe section. Much of this fill sloughed off from the sides as the pipe was raised, but dirt had to be hauled and dumped into the ditch to give the pipe final support.

Joint Sealing

When the entire section had been lifted to the correct grade and suspended by the slings, it became necessary to repair and seal the joints. This was accomplished by first grouting the outside of the pipe as far as possible around the periphery. Because the bottom third of the pipe was full of water, however, it was impossible to seal this portion of the joint from the outside. It was decided, therefore, to work from the inside of the pipe to seal this portion of the joint and dry the ditch.

This involved attempting to stop the

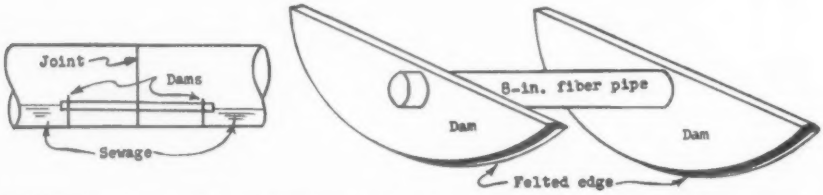

FIGURE 9.—Segmental wooden dams and a piece of 8-in. fiber pipe allowed grouting of joints in the dry from inside the raised pipe.

flow of sewage (about 9 m.g.d.) for short intervals so that men could work inside the line. It was deemed possible to hold up this flow for 3 hr. without doing any damage, so a bulkhead was built in the sewer at a manhole located about 1,000 ft. above the repair job. A 2-ft. by 2-ft. square gate that could be opened and closed as the need developed was provided at the bottom of this bulkhead. It was figured that this opening would just about take care of the normal sewage flow.

Because the men were afraid to work in the line below the impounded water, a second bulkhead was built in another manhole about 500 ft. above the job. As an additional safety measure, an escape hatch was cut in one of the pipe sections so that a quick means of exit would be available.

As could be expected, it was impossible to shut off the sewage flow completely, because of pressure leaks as the water built up behind the bulkheads. To remedy this, two movable dams were made of wood and connected with a length of 8-in. fiber pipe (Figure 9), so that the water could flow over the dry space between the dams.

By placing the dams in place and holding them down with a couple of sandbags, it was possible to clean out the intervening joint and grout it. To be able to turn the water back over the joint, it became necessary to use an admixture to make the grout set up at an accelerated rate. The product used in this case was SIKA, a liquid manufactured by the Sika Chemical Corp., Passaic, N. J. It is added to the water used in the preparation of grout; and by its proper use concrete can be made to set in a space ranging from 20 sec. to 20 min. By using this material, the joints were completely sealed from the inside as the dams were moved down the line from joint to joint. Because the sewer could be closed off for only 3 or 4 hr. at a time, this sealing was a tedious process.

After the joints were sealed, the river backed up the sewer on three separate occasions, flooding the work to a depth of 7 or 8 ft. Although this was inconvenient and delayed the progress of the job, it did water-tamp the backfill around the pipe. (Subsequent test holes dug beside the pipe showed no excessive amount of water, whereas when the job was started the water was standing to a depth equal to the depth of the water in the line.)

Because of the firm condition of the dirt around the pipe after the joints were sealed, it was believed that sufficient bearing capacity was evident so that the pouring of a supporting concrete mat was omitted.

Patching of the square holes cut in the top of the pipe to admit the lifting hook was a simple matter. Backfilling completed the job.

Benefits and Cost

It was noticed that the correction of alignment lowered the level of the water in the entire trunk line above the job site. This, in turn, allowed a quicker runoff of tributary lines and prevented manholes from blubbering when the lines were surcharged with infiltration.

The cost of the job, partly because of its experimental nature, was about $10,000. Although this may seem high, it must be remembered that the sewer service was not interrupted, even though the work was done under unusual conditions. It was a job that had to be done, because under existing conditions the line eventually would have collapsed completely.

CUSTOM-BUILT TRUCK FOR SEWER MAINTENANCE WORK

By Alvin A. Appel

Superintendent, Sewer Maintenance Division, Bureau of Sanitation, Los Angeles, Calif.

For many years the Sewer Maintenance Division of the City of Los Angeles has used a 1½-ton open, canopy-covered truck in the performance of general sewer maintenance work. Although this unit proved most durable and provided ready access to the many articles of equipment required on the job, the open body (Figure 1) did not provide the necessary protection from inclement weather for either the equipment or the per-

FIGURE 1.—Old type of truck used in general sewer maintenance work.

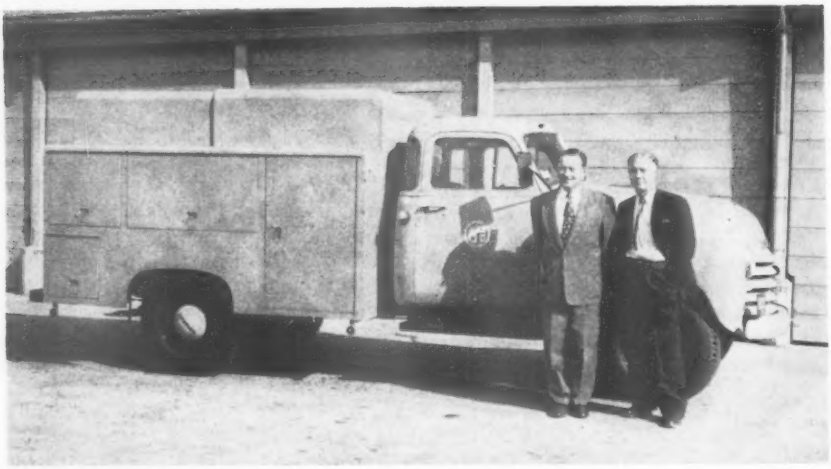

FIGURE 2.—New type of truck developed for sewer cleaning. With slight modification this type is adaptable for use in general sewer maintenance work.

sonnel, and could easily become unsightly unless constantly checked and cleaned. An additional disadvantage was that when small tools are not in a regular place and under lock, they can be readily lost.

To rectify the undesirable features mentioned, and to more properly provide for the storage of the special tools required in the extensive cleaning program carried on by the Division, a special body (Figure 2) was developed with the idea in mind that, with certain modifications, it will be used in sewer inspection work, replacing the open-canopy type.

The truck as constituted is small and compact, with all equipment covered, out of sight, and under lock. The sliding canopy permits greater working space in the truck body if required, as well as providing coverage for heavy equipment and personnel. When fully extended it gives a compact and pleasing appearance. As most of the work performed by the crew requires the truck to be parked in streets carrying heavy traffic, the entire unit has been painted a burnt-orange color with black and white striping across the rear section, thus providing immediate visibility to motorists and maximum protection to the maintenance crew.

As this is the Division's first design for this specific type of work, certain refinements no doubt will be worked out for future units. However, it is felt that the change in design will provide greater operating efficiency, as well as pleasing public appearance.

THE DAILY LOG

Kenosha, Wisconsin

By Frank I. Vilen, *Superintendent*

January 25—Every alternate year we have been buying a complete set of rocker arms for our gas engines. An examination of the used ones revealed that the only wear was on the head of the rocker where it strikes the top of the valve; the bushings invariably check O.K. By building up the head of the rocker arms with a weld and grinding to size, we are able to use the rockers over and over again. The cost of welding and grinding is about $1.00 per rocker arm; the cost of a new rocker is $5.67.

February 10—A telephone call from a local mill advised that it would be necessary to dump a 5,000-gal. tank of acid pickling liquor with a pH of 0.9. This has usually been transferred to a holding tank and pumped to the sewer in small amounts. On this occasion, the line to the holding tank failed, hence the necessity of dumping the entire tank to the sewer. We suggested neutralizing the acid to protect the sewers and structures en route to plant. When the stuff did get to the plant, the pH was 6.9, so it gave no trouble of any kind.

March 7—We are pumping down our No. 4 clarifier to remove the heavy clay and sand in the hopper. This material seems to bridge over the suction bell, and it cannot be moved with the sludge pumps. In addition to the large quantity of sand and clay, which had to be diluted with much water to get it pumped out of the hopper, the cleaning operation turned up a piece of galvanized pipe, a box wrench, and a long drift pin.

March 23—With the cooperation of the local Police Department, we have set up a call system for the protection of the operators. When only one operator is on duty, he is to call the police station each hour. Failure to call will bring a squad car down to see if he is

O.K. and has not met with an accident.

April 18—Started the major task of replacing all clarifier flight chains with new ones. The original chains are completely worn out after 10 years of service. (The flights are operated continuously.) Work on this project is proceeding satisfactorily. Eighty-five per cent of the cost of this replacement (representing the original cost) was paid from our depreciation reserve account, to which an annual appropriation is made just to cover these major replacement expenditures.

April 27—When it became known that your logger had been asked to write the weekly bulletin for the local Kiwanis club, there were the usual wise-cracks about miasmal emanations from the sewage plant. It's all in good fun and we have learned to roll with the punch. We tell people that our job is to help safeguard the health of the community in which we live. As in the story of the two bricklayers—one of whom just laid bricks, whereas the other knew he was building a cathedral—our 'cathedral' is to do the best possible treatment job as a protection for our citizens. No person in sewage treatment work needs feel that his job is in any way inferior to another. We believe in telling people about the importance of sewage treatment and do so at every opportunity.

May 6—Did you ever throw away a rubber sludge valve check ball because something had gouged a chunk out of it? We don't any more. The vocational school machine shop made us a vulcanizing mold, and we have damaged check balls vulcanized at a local tire repair shop. There's a lot of satisfaction in saving a dollar here and there in plant operation.

May 22—Sold 4½ tons of old flight chains to a local scrap dealer at a price of $32 per ton.

May 24—Had the fun of taking 40 children from a 9th grade science class through the plant. To explain sewage treatment to youngsters so that they will get something out of it is quite a challenge.

May 29—One of our more ribald neighbors argued that, inasmuch as he had for many years been a contributor of the material with which we work at the treatment plant, he should receive dried sludge for his lawn for nothing. We simply told him that if he could recognize his contribution and furnish conclusive proof thereof he could have it without any charge.

June 4—Our digester embankments were planted with a type of very thorny rose shrub. Maintenance and weeding had been desultory, as no one had the temerity to get in among the shrubs without a full suit of armor. When we learned that the Park Department wished to give away a quantity of sod, the roses were yanked out with a chain attached to the plant truck; the sod was hauled in and we now have pleasing and easily maintained grassy slopes. Incidentally, I wonder how many plants are situated as we are. The Kenosha plant is located at the southerly end of Third Avenue, which is one of the best residential areas in the city. A block to the north, and abutting on plant property, is a new residential development with homes in the $30,000 to $40,000 price range. Immediately to the west is another such area. Adjoining the plant on the east is a popular public recreation area and a bathing beach. A lot of people combine their recreational activities with visits to the plant, especially on week ends. We really have to keep this place spic and span at all times.

June 27—Today marks 24 months of service from a set of chevron-type packing rings in the No. 2 sludge pump (see THIS JOURNAL, **24**, 3, 327; Mar., 1952).

June 11—There is an accumulation of sand in the clarifier hoppers again. The trouble occurs after each prolonged storm flow. This will be the fifth consecutive month in which the clarifiers have had to be dewatered to get rid of sand accumulations.

July 5—Daughter Sandra, watching me total up the columns for the monthly operating data report, discovered that the job requires 24 ft. of adding machine tape. No wonder this is the one routine job I detest the most!

September 25—Our exhaust gas heat exchanger tubes have corroded and are leaking badly. They are located among a maze of pipes and under a balcony overhang so that we cannot lift them with the crane. After a lot of hard work and some cussing, we finally got them out and to a local boiler shop for retubing.

October 8—Very interested to read in a previous "Log" (see THIS JOURNAL, 23, 10, 1323; Oct., 1951) about Dave Backmeyer's experience with exhaust gas heat exchangers. He must have had a much more serious corrosion problem than we have. Our exchangers are being retubed with wrought iron and we hope to get another 11 years of service out of them.

November 13—A total of 1.84 in. of rain up to 5:30 PM today. Several storm-water overflows were found plugged with sand and gravel washed in by storms on the lake: many basements were flooded as a consequence. We cannot handle these excessive flows and are limited by our pumping capacity in helping to relieve such a situation. Our interceptor invert elevation is − 7.0 city datum. All of the flow must be lifted about 25 ft. to the operating levels and there is no way of bypassing until after the sewage is pumped.

December 17—Each year about this time we enjoy getting into the holiday spirit and put up Xmas decorations complete with a tree and all the trimmings. Colored lights are placed around the plant entrance, adding a touch of friendliness and good cheer for the holidays.

January 13—Started the routine annual overhaul of the sewage gas engines. Two cylinders are badly scored and will have to be rebored 0.040 in. oversize. Of course that means fitting new pistons and rings. The carbon deposit is very hard and some seems to have gotten past the rings to damage the cylinders. Our oil "expert" suggests that a "soft-carbon" type of oil will prevent a recurrence of this condition.

January 21—One of the operators slipped on a patch of ice today. A resulting pain in his groin was diagnosed by the doctor as a hernia. He will be off duty for several weeks, which will require some schedule changes and, of course, there will be one less man available for urgent work around the plant.

February 6—We have long been aware that our sludge temperature thermometers do not give a true picture of the heat, or lack of it, in the digesters. Once a week, therefore, we are going to pump for a few minutes from all drawoff levels to give us a better idea of temperatures. We have found that trying to measure temperatures by samples through the top of the digesters is not satisfactory. By the time a sample is obtained, several minutes have elapsed and the sample has cooled off.

February 15—We frequently have trouble with stuffing box breakage on the sludge pumps. This is not due to drawing them down too tight, as one would suppose. The breaks usually occur at the bolt flanges, and occasionally a bolt snaps off. The trouble invariably occurs when very heavy sludge, with probably some sand, is being pumped.

March 6—Routine check of the interceptor orifices today disclosed one of them plugged by an 8-in. diameter log 6 ft. long. It was so tightly wedged in the opening that we had to wrap a chain around it and pull it out with the truck.

March 15—The 1½-ton dump truck is being equipped with a front end loader. We expect to get a lot of use from this in moving sludge to stockpiles, plowing snow, and loading grit.

March 21—A rigid preventive main-

tenance schedule and inspection of all plant equipment has been instituted. This is a continuation of our former policy, except that all equipment is now listed on a chart with scheduled inspection periods ranging from daily checks to intervals of six months. The schedule is based on our many years of experience as to possible sources of trouble. An experienced and conscientious operator has been promoted to maintenance foreman, and it is his duty to see that the schedule is followed. This should help prevent those breakdowns which might occur due to neglect and carelessness.

A student from a nearby college spent an entire day at the plant copying our weather data. He is working on a project to correlate cosmic radiation with changes in weather. It surely is refreshing to talk with someone whose head is in the clouds. Ours is usually in some manhole!

TRICKLING FILTER ROACH INVASION

By George T. Lohmeyer

Superintendent, Sewage Treatment Plant, University of Florida, Gainesville, Fla.

"Like a small-scale review of the Biblical plague of locusts" would be an apt description of the scene presented at the standard-rate trickling filter of the University of Florida sewage treatment plant in May, 1953, when it was flooded for *Psychoda* control. In this case, however, the insect hordes

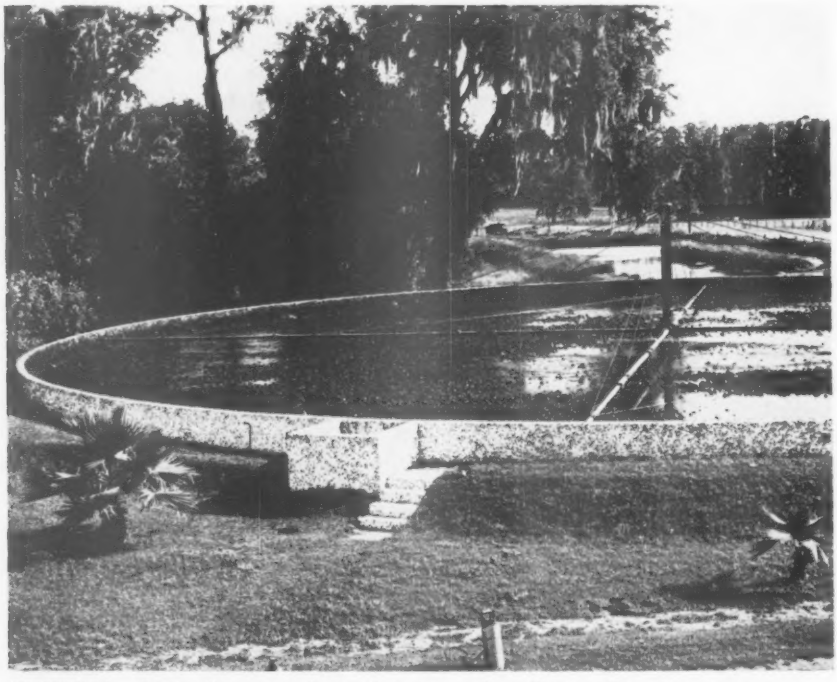

FIGURE 1.—As flooding proceeds, roaches emerge from filter media. Note hand pressure spray used to apply chlordane.

FIGURE 2.—Horde of cockroaches "erupts" from media as trickling filter is flooded. Note mass of insects on rocks, on inside of wall, and at outside base of wall.

were not locusts, or even *Psychoda*: they were just plain cockroaches.

Since the time of placing the plant in operation in September, 1947, neither the 112-ft. diameter standard-rate filter nor the adjacent 40-ft. diameter high-rate filter had been flooded for *Psychoda* control. In fact, flooding would have interfered seriously with bacteriological examinations being carried on with filter depth samples in connection with research work. Moreover, trickling filter flies had not been a serious problem.

The flooding operation on the standard-rate filter was finally decided on largely because the night operator had reported that roaches had been collecting on the outside filter walls at night. It must be emphasized that only scattered roaches were seen on the standard-rate filter walls, never on the walls of the adjoining high-rate filter, and then only at night. No young roaches were ever seen, only adult specimens. Apparently the young remained within the filter media at all times.

Eruption of Roaches

Flooding of the 6-ft. deep bed began at 11:00 AM, and by 4 PM of the same day the water level was within 4 in. of the filter surface. The filter media, 2-in. to 4-in. Birmingham slag, soon looked as if it had been replaced with another type of media—a moving mass of roaches so thick that the rocks were completely covered (Figure 1). As the

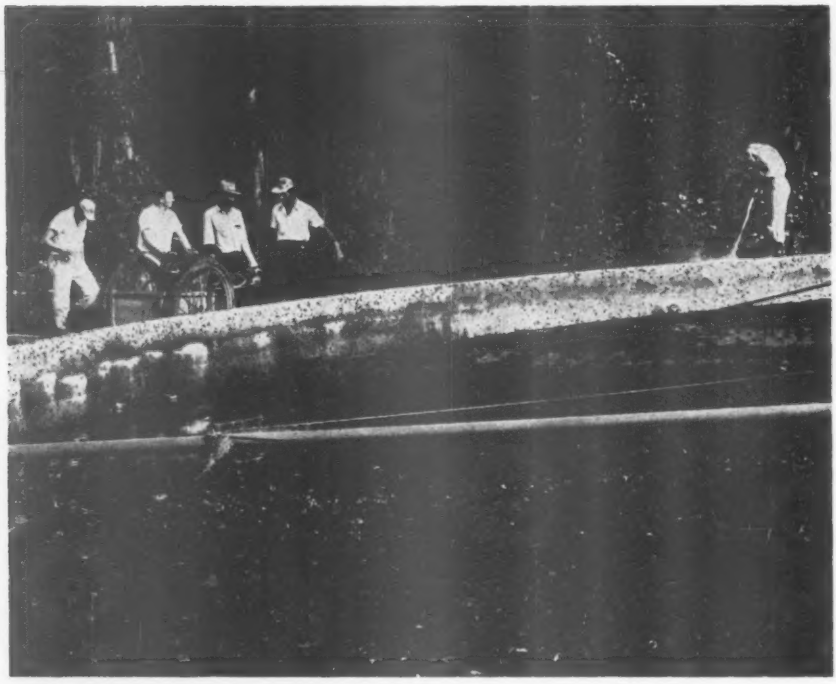

FIGURE 3.—Power spray crew works on roaches still alive after bulk of roach army had been destroyed. Proximity of probable roach source in woods is emphasized in this view.

water rose the filter resembled an erupting volcano, erupting not with lava, but with millions of roaches (Figure 2).

The advancing hordes of insects were met with 5 per cent chlordane, dispersed from three sprayers by an alert entomology department and the following day millions of dead roaches floating on the flooded filter were skimmed off with hardware cloth. By actual count, 26 wheelbarrow loads of roaches were limed and buried. This amounts to a minimum volume of 2.58 cu. yd. of roaches! And several times that quantity died in the adjacent woods (Figure 3).

Possible Explanations

In "normal" operation roaches can be controlled on filters by periodic flooding. In this particular case, however, no means of controlling filter flies—or roaches—was practiced during the last 5 years because of the type of experimental work being carried on with the filter. It is doubtful, therefore, that the roaches "took over" the filter when it became idle just prior to being flooded. More likely, the increase was over a long time and was the result of natural migration from a source in the adjacent woods, plus natural multiplication in the favorable environment of the filter.

An excellent source for initiation of a roach population exists in a small heavily-wooded area lying within 30 or 40 ft. of the infested filter, wherein is located a "bull pen" for discarded lumber, roofing, cabinets, etc., all perfect roach havens. Consequently, there may have been a constant migration to the filter over a period of years.

Once the filter was infested, the readily available food, perfect temperatures, ideal dark cracks, and protection from preying birds could only be expected to result in the highest roach reproduction rate.

Effect on Filter Efficiency

The hydraulic loading on the filter has ranged from 2 to 3 m.g.a.d., both before and since the deroaching operation. Apparently the eviction of the insects has had no deleterious effect on the filter operation, as the percentage B.O.D. reduction through the infested unit has remained unchanged.

Needless to say, future planning includes periodic flooding of the plant filters, regardless of whether or not roaches are seen!

INTERESTING EXTRACTS FROM OPERATION REPORTS

Annual Report of the Muskegon, Mich., Sewage Treatment Plant for the Year 1952

By C. T. Mudgett, *Superintendent*

General

The population of Muskegon by the 1950 census was 48,429, of which some 90 to 95 per cent was connected to the sewer system, which is tributary to the primary-type treatment plant. Separate sludge digestion is provided, with chlorination of the plant effluent.

Personnel

The operators' schedule for a 42-hr. week is unique and much liked by the men. Each works 9 days and is off 3 days, moving ahead one shift after each 24-day period. The schedule is made up for a year or more in advance and the operators are able to make personal plans accordingly. The 42-hr. week was chosen in preference to a 44-hr. week with holidays. Actually, however, the employee gets the equivalent of 13 holidays.

Lift Stations

Considerable trouble was experienced with operation at some of the lift stations, due to high lake levels and resulting high ground-water infiltration. High levels in storm overflows also contributed to the difficulties by necessitating raising of weirs to prevent backflow into the sewer system.

Plant Units

A gas flame in the covered grit pit of the detritor during the winter keeps ice from forming on the cleaning ramp and permits year-round operation.

Six baffles placed in the chlorine contact chamber improved the bacterial kill at the mid-point, but did not greatly affect the final results.

Two-stage digestion was employed as usual, but no transfers were made from the bottom of the primary to the secondary. Instead, an occasional pumping of sludge was made from the bottom of the primary to the filter or truck. This avoided transfer of sand to the secondary digester, as the sludge inlet in the primary is at the center and sand stays in the area where it can be removed.

Of the 1,187,500 gal. of digested sludge removed, 539,600 gal. were filtered and 647,000 gal. were hauled to new park developments by the tank truck. The liquid disposal served the dual purpose of providing humus and food for the grass planted later and stabilized the sand to prevent its blowing.

Good results were obtained by vacuum filtration of the sludge handled. Ferric chloride consumption av-

eraged 2.7 per cent, and lime consumption averaged 9.1 per cent. Production averaged 4.9 lb. of dry sludge solids per square foot of filter area per hour. The Canton flannel filter cloths were acid washed when necessary. Sludge cake was sold for $3.75 per 3-cu. yd. load to anyone within 6 mi. of the plant.

Grounds

A major headache was eliminated by discontinuing the bathing beach at the plant site and seeding the area to lawn. High water in the river killed out some grass and trees on the grounds, but the major damage was done by fishermen stripping the lawns to get worms. This last was considerably reduced by prohibiting fishing from the banks of the pond and river. Boat docking also was prohibited, although a launching ramp provided for those who bring their boats by trailer was used extensively.

Operation data for 1952 are summarized in Table I.

TABLE I.—Summary of 1952 Operating Data, Muskegon, Mich., Sewage Treatment Plant

Item	Average	Item	Average
Rainfall (in.)	29.91	Removed (gal./m.g.)	1,950
Pop. equivalent	61,100	Tot. solids (%)	4.85
Sewage flow (m.g.d.)	7.13	Vol. solids (%)	75.1
Grit (cu. ft./m.g.)	0.9	Digested sludge:	
Volatile (%)	4.0	Removed (g.p.d.)	3,200
Susp. solids (p.p.m.):		Tot. solids (%)	8.76
Raw sewage	160	Vol. solids (%)	50.6
Settled	71	Supernatant (g.p.d.)	11,600
Removal (%)	55.6	Solids (%)	0.34
Susp. vol. sol. (p.p.m.):		Volatile (%)	55.6
Raw sewage	124	Sludge gas:	
Settled	55	Produced (cu. ft./day)	41,700
Removal (%)	55.6	Used (cu. ft./day)	13,800
Total solids (p.p.m.):		Wasted (cu. ft./day)	27,900
Raw sewage	555	Sludge dewatering:	
Settled	460	Dry solids, total (tons)	366.7
Removal (%)	17.1	Sol. yield (lb./sq. ft./hr.)	4.9
Tot. vol. sol. (p.p.m.):		Fe Cl_3 (%)	2.7
Raw sewage	239	Lime, hyd. (%)	9.1
Settled	168	Chlorine:	
Removal (%)	29.7	Consumed, total (lb.)	100,650
B.O.D. (p.p.m.):		Consumed (lb./day)	508
Raw sewage	175	Applied (p.p.m.)	8.3
Settled	133	Residual (p.p.m.)	0.6
Removal (%)	24.0	Oper. and maint. cost. ($):	
Raw sludge:		Total	65,892.57
Removed (g.p.d.)	13,900	Per m.g.	25.25

Report on the Operation and Maintenance of the Easterly Sewage Treatment Plant, Cleveland, Ohio, for the Year 1951 *

By John J. Wirts, *Superintendent*

General

Operating conditions, in general, were similar to those existing in previous years. Two of the four grease flocculation units, which have been out of service for several years, were put back in service, with perforated pipes instead of porous plates providing air diffusion. Primary settled sewage flow to the aeration units was restricted to 100 m.g.d. from November 1 on, due to inability of the Southerly plant to

* For last previous extract see This Journal, **24**, 11, 1424 (Nov., 1952).

treat the volume of sludge produced at higher flows.

The average daily flow of 106 m.g.d. handled by the plant represented a decrease of 1.7 m.g.d. from that treated in 1950. Air requirements were maintained at an average of 0.74 cu. ft. per gallon of settled sewage, or 0.10 cu. ft. per gallon less than in 1950.

B.O.D. reduction averaged 90.1 per cent; suspended solids reduction averaged 88.4 per cent. Sludge pumped to the Southerly plant averaged 3.3 per cent total solids. The average number of employees during the year was 61, as compared with 67 during 1950.

Comminutors and Detritors

To maintain the four 54-in. comminutors at peak efficiency required frequent retooling of the cutting elements. This included rebuilding 923 teeth, 22 combs, and 102 shear bars for use as replacements. The third new replacement machine was installed during the year, with preliminary arrangements made for the fourth.

In May, continuous 24-hr. operation of the detritor rakes was abandoned in favor of operating them only as necessary. General overhaul of detritors No. 2, 3, and 4 put these units back in excellent condition.

Force Main

The sludge force main to the Southerly plant was cleaned several times during the year. In March, the cleaner became stuck in the line and it was necessary to cut the line in two places to remove heavy grit accumulations ahead of the cleaner. Two additional blowoff valves were installed in one 13,500-ft. section of the line, necessitating conversion of two clean-out vaults into blowoff vaults.

Aeration

Steel aeration frames and clean plates were installed in aeration tanks No. 7 and 15. The 11 stainless steel air manifolds installed experimentally in tank No. 8 in 1947 were inspected in November and found to be in the

TABLE II.—Summary of 1951 Operating Data, Easterly Plant, Cleveland, Ohio

Item	Average
Raw sewage flow (m.g.d.)	106.6
Settled sewage flow (m.g.d.)	98.7
Grit removed (cu. ft. per m.g.)	2.66
Screenings (cu. ft. per m.g.)	0.17
Suspended solids (p.p.m.):	
Raw	227
Settled	138
Effluent	26.3
Per cent removed	88.4
B.O.D. (p.p.m.):	
Raw	128
Settled	81
Effluent	12.7
Per cent removed	90.1
Oxygen consumed (p.p.m.):	
Raw	92
Settled	63
Effluent	22.7
Per cent reduction	75.3
Dissolved oxygen (p.p.m.):	
Raw	2.5
Aerator influent	2.4
Aerator effluent	2.7
Final effluent	2.5
Ammonia (p.p.m.):	
Raw	12.9
Settled	8.5
Effluent	9.3
Nitrite, effluent (p.p.m.)	0.3
Nitrate, effluent (p.p.m.)	0.8
Sludge pumped to Southerly plant, total (m.g.)	190.99
Per cent moisture	96.7
Activated sludge:	
Total solids (p.p.m.)	5,480
Volatile solids (%)	61.2
Mixed liquor susp. sol. (p.p.m.)	1,277
Sludge index (ml./gram)	62
Air (cu. ft./gal. sett. sew.)	0.75
Postchlorination:	
Days applied, total	94
Application rate (p.p.m.)	3.7
Residual maintained (p.p.m.)	1.1
Bacterial count; agar plates at 37½° C. (1,000 per ml.):	
Raw	1,300
Effluent	40
Per cent reduction	97.5
Presumptive *B. coli* (1,000 per ml.):	
Raw	112
Effluent	16.3
Per cent reduction	85.5
Plant costs ($ per m.g.):	
Operation and maintenance	17.00
Administration	5.47
Total	22.47

original condition, with only the slightest pitting. In contrast, the 11 plain steel manifolds protected with various combinations of primer and bitumastic paints, installed in tank No. 13 in 1947, were covered with rust.

Plug valves on the air lines of tanks No. 7, 13, and 15 were disassembled, thoroughly cleaned, and then changed from stick lubricant to cup grease and Alemite fittings. The alteration was justified by the resulting ease in operation of these valves.

Final Clarifiers and Concentration Tanks

Final clarifiers No. 1 and 2 were used all year as low-rate concentration tanks for waste activated sludge. Sludge pumped directly into the Southerly force main from these tanks averaged 3.6 per cent total dry solids.

Inspection revealed that the ball bearings of No. 12 final clarifier had worn a race in the turntable base and diffuser casting to a depth of 0.305 in. Repair alternates include replacing the balls to regain 0.020 in. of the wear; replacing with oversize balls, necessitating machining of the internal gear to fit; installing a completely new head of more modern design; or replacing the turntable top with a newer modified split ring having a replaceable wearing strip. Delivery uncertainties resulted in a decision to replace the worn balls in the same size and relieve the internal gear by raising it 3/16 in. Several of the other final settling tanks have given indications of being in similar condition. The chief problem to be solved is the rigging to lift the heavy castings.

Operation data for the year are summarized in Table II.

Report on the Operation and Maintenance of the Westerly Sewage Treatment Plant, Cleveland, Ohio, for the Year 1951 *

By John O. Barrett, *Superintendent*

The total sewage flow of 13,194.8 m.g. was only 4.8 per cent below the record flow of 1950.

The grease aeration channels, now considered to be secondary grit channels, have been effective in removing fine grit and silt that gets through the grit channels. It is desirable to clean these channels at least once a month, but this schedule could not be adhered to because of weather conditions, irregularity of grit crane operation, and difficulties with the detritor when it was overloaded. The present stop-plank method of closing off the aeration channel flow to permit cleaning is unsatisfactory and should be improved.

Sedimentation

Imhoff gas vent scum was this year removed and pumped directly to the filtration sump whenever conditions permitted. Practically no gas vent foaming occurred during the year. Numerous repairs were made to the concrete surfaces on the Imhoff tanks and quite a number of the Imhoff gas vent lids were replaced by new lids made of fir. Some of the lids were reinforced with steel plates.

Chlorination

Because of the proximity of recreational facilities, every effort was made to maintain a chlorine residual in the plant effluent at all times during the summer vacation season. Residual chlorine determinations were made hourly whenever it was practical to do so, the chlorine feed being adjusted in accordance with the chlorine demand. A chlorine residual of 1.69 p.p.m. was maintained in the effluent 66.7 per cent of the time covered by determinations.

* For last previous extract see This Journal, **24**, 11, 1427 (Nov., 1952).

Between June 12 and September 11 a total of 288,900 lb. of liquid chlorine was fed at a total cost of $8,551.44. To prevent odors, retard bacterial growth, and reduce gas vent foaming, a dosage of 6.58 p.p.m. chlorine was added to the plant influent, representing a feed of 122,864 lb. The balance of 166,036 lb., or 7.43 p.p.m., was added to the effluent.

When the presence of floc in the effluent indicated strong industrial wastes, the feed was adjusted to a predetermined maximum only. Near the close of the season, pre-chlorination was discontinued and the entire demand was fed by post-chlorination equipment. Results indicated that an equal quantity of chlorine was required whether it was fed only into the effluent or divided between the influent and effluent.

Sludge Digestion

Operation of the digesters was practically identical with that of previous years. No gas vent scum was added to the digesters, but still the scum accumulation averaged about 9 ft. in each tank when they were pumped down. Cleaning of the digesters started in August and progressed at intervals of about two weeks until all six were cleaned. The scum was added to the storage tanks and disposed of as rapidly as possible by hosing and pumping to the filters.

The intensified gas vent washing program retarded the removal of scum from the storage tanks. Although approximately 100 tons of scum were forked off and stored in a pile east of the Imhoff tanks, there was still a considerable amount left on the tanks when cold weather set in. This accumulation interferes with the addition of digested sludge to the storage tanks, as the outlet ports become blocked, preventing the overflow of supernatant.

Filtration

After the first few weeks of the year the filters were operated on a two-shift basis, eliminating the night shift. Three filters were frequently in operation when sludge was plentiful or the demand for cake was great. Digested sludge was pumped direct from the digesters throughout the year, although gas vent scum and storage tank scum were added to the filter sump in quantities as high as 50 per cent of the total additions on some days. The mixture filtered quite satisfactorily, but the quantity of scum was limited because of the blocking of the chute to the outside conveyer.

The average chemical dosages of 2.78 per cent ferric chloride and 12.9 per cent lime, or 11.5 per cent calcium oxide, were appreciably below those of the last four years.

A total of 7,215 tons of filter cake was produced. This amount is considerably lower than that produced in many years. The rate of cake production of 3.66 lb. of dry solids per square foot of filter area per filter hour operation, was the greatest in several years.

The average filter cloth life was about normal, being 203 hr.

Two additional trap doors were cut in the top of the lime bins and covers were fabricated from ¼-in. steel plate. These doors permit the leveling of lime in the bins.

Incineration

Of the 7,215 tons of filter cake produced, only 628 tons were incinerated. This amount represents 8.7 per cent of the total. Practically all of the cake incinerated was burned in four months of the year. The total cake incinerated again took a radical drop when compared with the 2,717 tons burned last year.

A total of 6,587 tons were removed by the public for soil conditioning purposes.

The moisture content of the cake incinerated was 66.1 per cent. This is a little higher than the previous two years. Cake was incinerated at a rate of 1.29 tons per incinerator hour. The maximum cake incinerated in one day was 22.7 tons.

A total of 11,100,000 cu. ft. of digester gas at standard conditions was required by the incinerators. Of this total, 10,500,000 cu. ft. was used to maintain standby temperatures. The balance, 600,000 cu. ft., was used during incineration periods. (It is well to note that if the incinerator gas figures are used for comparison with those of other plants, they do not represent a minimum requirement. This plant has an abundance of gas in the summer months and gas is used extravagantly, since it is more or less a means of wasting gas. Gas burners are kept burning while incinerating at times to lessen the tendency for incinerator temperatures to vary with fluctuations in the moisture content of the cake being fed.)

Some cake was incinerated for the purpose of suppling heat to the econo-

TABLE III.—Summary of 1951 Operating Data, Westerly Plant, Cleveland, Ohio

Item	Average
Raw sewage flow (m.g.)	36.2
Grit removed (cu. ft. per m.g.)	2.96
Per cent volatile	22.6
Screenings (cu. ft./m.g.)	0.53
Suspended solids (p.p.m.):	
Raw	251
Imhoff tank effluent	177
Per cent removed	29.6
B.O.D. (p.p.m.):	
Raw	189
Imhoff tank effluent	150
Per cent removed	20.4
Oxygen consumed (p.p.m.):	
Raw	145
Imhoff tank effluent	129
Per cent reduction	11.0
Total bacteria (1,000 per ml.):	
Raw	3,217
Imhoff tank effluent	1,119
Presumptive *B. coli* (1,000 per ml.):	
Raw	475
Imhoff tank effluent	136
Prechlorination:	
Days operated	69.2
Average dose (p.p.m.)	6.58
Postchlorination:	
Days operated	83.7
Average dosage (p.p.m.)	7.43
Average residual (p.p.m.)	1.69
Raw sludge to digesters:	
Number of additions per month	75
Temperature (° F.)	62
Volatile solids (%)	64.7
Total solids (%)	6.18
pH	6.5
Alkalinity as $CaCO_3$ (p.p.m.)	770
Digester supernatant:	
Total solids (%)	1.31
Volatile solids (%)	52.1
pH	8.1
Alkalinity, as $CaCO_3$ (p.p.m.)	2,570

Item	Average
Gas production:	
Daily production (cu. ft.)	145,300
Cu. ft. per lb. volatile solids	7.7
CO_2 (%)	27.5
Utilization of digester gas:	
Digester heaters (%)	32.7
Building heaters (%)	16.2
Incinerators (%)	20.9
Wasted (%)	30.2
Digested sludge vacuum filtered:	
Total solids (lb. per month)	453,700
Total solids (%)	8.6
Volatile solids (%)	51.2
pH	8.1
Alkalinity, as $CaCO_3$ (p.p.m.)	2,720
Chemical dosage for vacuum filtration (%):	
Ferric chloride	2.78
Lime	12.9
Calcium oxide	11.5
Sludge filtration:	
Filter cake:	
Moisture (%)	66.1
Volatile solids (%)	44.6
Pounds dry solids per sq. ft. filter area per hr.	3.66
Filter cake per filter hour (tons)	0.89
Average filter cloth operating life (hr.)	203
Sludge filter cake incineration:	
Tons per month incinerated	52
Tons per incinerator hour	1.29
Tons used for soil conditioner	7,219
Fuel oil used:	
Gal. per ton of filter cake	0.707
Gal. per ton of dry solids	2.070
Gas used:	
Cu. ft. per ton of filter cake	978
Cu. ft. per ton of dry solids	2,862
Plant costs ($ per m.g.):	
Operation and maintenance	12.28
Administration	5.47
Total	17.75

mizer, which in turn provides hot water for the heating of the incineration building.

Fuel oil totaling 1,072 gal. was used as auxiliary fuel during periods of limited gas production.

Table III is a summary of operation data for the year 1951.

Report on the Operation and Maintenance of the Southerly Sewage Treatment Plant, Cleveland, Ohio, for the Year 1951 *

By Walter E. Gerdel, *Superintendent*

Sewage Flows

The metered raw sewage flow of 10,669.5 m.g. for the year 1951 was substantially under that of the previous years. This decrease was caused by the diversion of the Big Creek interceptor during construction activities.

The following distribution of sewage flows applies to the effluent from the Imhoff tanks:

Distribution	Flow (m.g.)	(%)
To aeration tanks	6,946.7	65.1
To trickling filters	2,358.9	22.1
By-passing sec. treat.	1,363.9	12.8

Imhoff Tanks

Foaming difficulties were practically non-existent for the first time in many years. It is evident that the relatively low sewage flow was in great part responsible for this very desirable condition. All of the digested sludge withdrawn from the Imhoff tanks was pumped to the vacuum filter unit or to the sludge drying beds, with the much greater volume going to the vacuum filters.

Abbreviated Aeration Unit

The aeration unit treated 6,946.7 m.g. of settled sewage. The air volume amounted to 0.48 cu. ft. per gallon of settled sewage. The effluent from this unit was given no further treatment and joined the trickling filter effluent to form the plant effluent. A reduction of 72.9 per cent of the suspended solids in the settled sewage, and 81.0 per cent of the 5-day B.O.D. was effected. The effluent averaged 32 p.p.m. in suspended solids and 12 p.p.m. in 5-day B.O.D.

The aeration tanks and final clarifiers were cleaned and other maintenance work was carried out during October, when the entire aeration unit was shut down for about three weeks due to the necessary activities of the contractor.

Trickling Filters

Due to the low flows treated, the aeration unit was able to take the greater portion of the flow, leaving comparatively small volumes to be handled by the trickling filters. Calculated results of the trickling filter effluent showed very poor performance: the suspended solids increased in the effluent by 24.6 per cent, whereas the 5-day B.O.D. removal amounted to only 7.8 per cent. Pooling of the beds persisted over extensive areas, even with the light loading.

A test hole 5 ft. in diameter and extending from the top to the bottom, was dug in No. 2 bed. All of the stone in this hole was removed for samples. It was found that on the average the voids in the filter media were 72 per cent clogged, and that there was practically no evidence of normal biological life present. This test substantiated previous tests made in 1947, and it has been concluded that the trickling filters are seriously clogged and of little use in their present condition.

Operation data for 1951 are summarized in Table IV.

* For last previous extract see This Journal, **24**, 11, 1429 (Nov., 1952).

TABLE IV.—Summary of 1951 Operating Data, Southerly Plant, Cleveland, Ohio

Item	Average
Rainfall (in.)	42.72
Raw sewage flow (m.g.d.)	29.2
Screenings (cu. ft. per m.g.)	0.54
Grit (cu. ft. per m.g.)	2.57
Per cent volatile	31.2
Abbreviated aeration unit:	
Flow (m.g.d.)	19.0
Per cent of total flow	65.1
Air used (cu. ft. per gal.)	0.48
Trickling filters:	
Flow (m.g.d.)	6.46
Per cent of total flow	22.1
Suspended solids (p.p.m.):	
Raw	202
Imhoff tank effluent	118
Filter influent	118
Filter effluent	147
Final effluent	60
Dissolved oxygen (p.p.m.):	
Raw sewage	6.2
Imhoff tank effluent	1.8
Plant effluent	5.6
River above plant	8.2
River below plant	7.9
B.O.D. (p.p.m.):	
Raw	125
Imhoff tank effluent	64
Trickling filter effluent	59
Final effluent	25
River above plant	8.6
River below plant	12.7
Oxygen consumed (p.p.m.):	
Raw sewage	78
Plant effluent	44
Final effluent	78
Sulfates in raw sewage (p.p.m.)	124
Imhoff tank sludge:	
Total solids (%)	9.3
Volatile solids (%)	43.6
Digester operation:	
Raw sludge:	
Volume, total (m.g.)	222.02
Per cent from Easterly plant	86.0
Per cent from Southerly plant	14.0
Dry solids (mil. lb.)	59.06
Volatile solids (mil. lb.)	36.60
Digested sludge:	
Volume (m.g.)	32.78
Dry solids (mil. lb.)	17.26
Volatile solids (mil. lb.)	7.91
Total solids (%)	6.14
Volatile solids (%)	45.8
Alkalinity (p.p.m.)	3,020
pH	7.3
Supernatant:	
Volume, total (m.g.)	188.85
Total solids (%)	1.33
Volatile solids (%)	52.6
Suspended solids (p.p.m.)	10,921
Gas production:	
Volume (1,000 cu. ft. per day)	709.9
Cu. ft. per lb. vol. solids	7.1
Per cent CO_2 in gas	31.3
B.t.u. (gross)	642
Gas utilization (per cent):	
Wasted	31.7
Digester heating	26.4
Incinerators	13.0
Gas engines	19.3
Building heat and misc.	9.6
Vacuum filtration of sludge:	
M.g. filtered, total	42.9
Mil. lb. dry solids, total	25.4
Chemicals used (%):	
Ferric chloride	4.65
Lime	14.78
CaO	13.20
Filter cake production:	
Tons dry solids, total	18,464.6
Per cent solids	28.5
Per cent vol. solids	38.5
Filter rate (lb. dry solids per hour per sq. ft. filter area)	3.35
Filter cloth life (hours)	439
Sludge incineration:	
Sludge cake (tons)	64,426
Sludge cake (tons per incinerator hour)	3.44
B.t.u. per lb. vol. solids	11,825
Filter cake moisture (%)	71.6
Filter cake per cent volatile	38.5
Plant costs ($ per m.g.):	
Operation and maintenance	23.36
Administration	5.47
Total	28.83

JOINT MATERIALS FOR SEWER REPAIRS *

By A. P. Collins

Division Engineer, Sanitation Division, Office of Los Angeles County Engineer and Surveyor, Los Angeles, Calif.

It is not intended that this paper cover the broad subject of joint materials for the construction of sanitary sewers, or even discuss the progress made to date in the search for the ideal joint material, if there be such a material. Furthermore, although it is undoubtedly true that a great deal of the maintenance man's grief arises from the deficiencies as to laying, jointing, and inspecting of the originally constructed sewer, these deficiencies also are outside the scope of this paper. Instead, the purpose here is to briefly discuss the subject of the joint materials available to the sewer maintenance man for the repair or replacement of portions of sewers that have failed.

To replace a broken length of pipe it is first necessary to locate, uncover, and expose the break, so as to ascertain the extent of the damage and the best method for repair.

Usual Repair Procedure

A single joint of pipe that is crushed or quartered is ordinarily replaced by buckling in a piece of similar length by first removing the failed pipe and removing the top half of the bell of the first joint downstream, as well as half of the bell on the new piece, placing it in the line with the new half-bell over the spigot end of the pipe upstream. The new pipe is then rotated 180° so that the half-bell is on the bottom, and the pipe is centered and secured by placing a gasket of twisted oakum and ramming it home with a yarning iron.

Cement mortar made of one part Portland cement and two parts plaster sand is then forced into the bells to completely fill the annular space. The upper ends of the oakum are then twisted and slightly overlapped, and securely held in place with stiff mortar. A cement collar about 2 to 3 in. thick and 5 or 6 in. wide is placed around the entire joint.

For best results in this type of repair it is necessary to shut off the flow in the line at the first manhole above

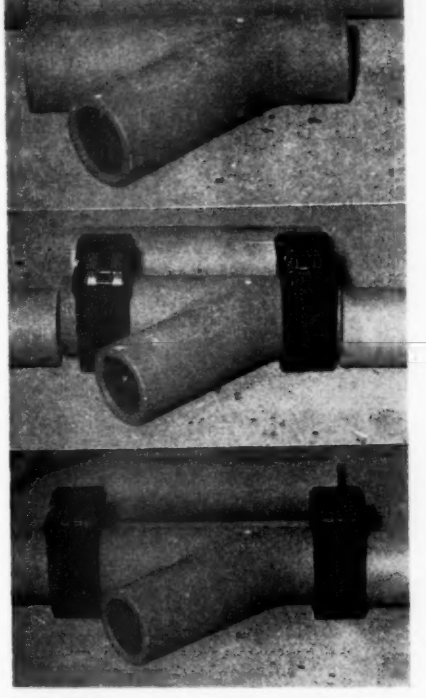

FIGURE 1.—Steps in insertion of wye in a line by means of Ceramic Weld joints.

* Presented at 25th Annual Convention, California Sewage and Industrial Wastes Assn.; Santa Barbara, Calif.; April 22–25, 1953.

FIGURE 2.—Field installation of tee in a line by means of Ceramic Weld joints. Gaskets, clamps, and forms are in place ready for filling with mortar.

the break. However, it can be done on a "live" sewer, but this usually entails considerable bailing in the trench after the pipe and oakum are placed before cementing can begin. As a further precaution, the water in the line should be let down slowly after placing the joint mortar. This is to guard against disturbing the pipe joints from a sudden rush of water or air.

Ceramic Weld Joint

A more recent technique used by Los Angeles County sewer maintenance forces is as follows. The broken pipe is removed. Part of the upper end of the downstream pipe, including the bell, also is removed by cutting this piece off squarely to leave an opening the length of a straight piece of spigot or plain end pipe. Pipe of suitable length is then placed in the line and jointed by means of Ceramic Weld rubber couplings.

The joint used in this procedure confines the sewage to the pipe by means of a rubber sleeve slipped over the ends of adjoining pipe sections and tightened by stainless steel band clamps. ((In a repair operation of the sort described, the center fin must be removed before the collar is slipped over the inserted pipe section.) The joint is then completed by filling the outer form (Figure 1) with a 1:2 cement mortar. Actual field installation of a tee using this type of joint is shown in Figure 2.

Adequate support under and at the sides of the pipe should be placed before backfilling the trench to eliminate the possibility of further damage to the line.

"Inner Tube" Joint

Recent failure of a considerable length of sewer line constructed in a location having a head of several feet of ground water over the pipe was handled by yet another method. The area was first unwatered by means of a well point system. The line was then

relaid with pipe having smooth bells and spigots, jointed by synthetic rubber gaskets. The gaskets were made like inner tubes for automobile tires and came collapsed and sealed by a metal clamp over the inlet to keep out air. Filling with a 1:1 slurry of Portland cement and fly ash was done under a pressure of 60 p.s.i. When the gasket was full and bulging the inlet tube clamps were pinched tightly shut to retain the pressure. This type of joint is not only watertight, but also provides slight flexibility.

Pipe Support

The repair just described was necessitated by failure of the line due to settlement caused by washing of fine silt through a coarse rock base into the pipe with infiltration water. Some thought is being given to use of fine granular base material, of the types used in highway work, in place of coarse rock in quicksand areas. This would tend to reduce the washing of extremely fine material from under and around the pipe.

Jointing in Wet Trenches

The Division has used extensively joints made with gaskets and forms, particularly in areas of high groundwater levels. These joints can be made successfully, even with water in the trench and pipe up to the spring line.

After the gasket and form are attached in the prescribed manner, the mortar for the lower half of the joint is placed with a cement gun and a hose, the hose being placed in the joint around the lower half and slowly withdrawn as the mortar is pumped in. This drives out any free water present and makes a solid cement joint. The top half of the joint is then filled with 1:2 mortar, being careful to get a good bond with the thinner mortar of the lower half.

Uses in New Sewers

In the construction of new sewers the Division specifies the types of joints already described, as well as joints made with two types of hot-poured compound—one a coal-tar base material and one a plastic base material.

TIPS AND QUIPS

Safety Program Pointers

Complete safety of employees depends on their desire to be safe at all times, both on the job and off. If this desire is lacking—if a man leaves his habits of safety on the job when he leaves his place of employment—something is lacking in his safety training. Particularly is this true when it is realized that the possibility of injury away from work is much greater than while he is on the job. At work he is being supervised; away from work he is on his own. Constant safety consciousness is a "must."

This, in effect, is the gist of an item in a recent issue of the *Safety News Letter* of the Public Employee Section, National Safety Council. Other noteworthy hints gleaned from the same source include the following:

It is very important—particularly if you give your employees a "going over" for not being careful, cautious, and safe—that those who do carry out their assignments in a safe and sane manner be recognized somehow for that accomplishment. One organization is reported as giving certificates to first- and second-year accident-free employees, with suitable attractive sterling silver pins being awarded to those with longer safety records. The awards are highly coveted, as they should be.

The same organization reports that most of its accidents involve young or inexperienced men, emphasizing the

ever-present need for more job training.

The National Safety Council recently published a "Handbook of Accident Prevention," written for the man who must divide his time between safety work and other responsibilities. Price of the 96-page book is $1.50.

Training, instruction, and supervision are not good training, instruction, and supervision unless each includes safety and accident prevention.

Know the work's hazards—don't learn of them by accident!

Operation "Purge"

As reported in the June, 1953, issue of *Sewage Gas*, quarterly news letter of the Boise, Idaho, sewage treatment plant, 80 per cent of the city's sewer lines were rodded at least once during the past winter. Using power equipment on a 5-day-a-week schedule, the efforts of the sewer maintenance crew have resulted in 30 per cent fewer emergency sewer calls than during the previous year. More important is the favorable public reaction to speedier relief from the inconvenience of a stopped sewer line and flooded basements.

The biggest headache in the sewer maintenance operation is reported to be locating manholes, particularly after the Street Department recoils or paves a street. It seems as though, besides experience, a "manhole ferret" needs bloodhound instinct, sharp eyes, and an extremely sharp sense of smell!

Syndet Comparator

A new color comparator for determining the anionic synthetic detergent content of sewage and other liquid wastes has been announced by W. A. Taylor and Co., Baltimore, Md. The anionic syndets are considered as the only ones affecting sewage treatment because their use far exceeds any others.

The basis of the apparatus, as described by Faust,* in an adaptation of the method based on colorimetric determination of the colored chloroform-soluble salts formed by reaction of the syndet with methylene blue. Comparison with color standards is said to complete the syndet determination in 30 min.

Pasadena Policies on Tree Troubles

Pasadena, famed for its Tournament of Roses, also is known for its beautiful, tree-lined streets. In the past, however, the trees occasionally proved more of a headache than a blessing, as thirsty roots penetrated the joints of non-metallic house sewers connecting the house drain with the main street sewer. Repairing the damage sometimes meant tearing up sidewalks and pavements at considerable expense, disturbance, and inconvenience to the community.

Hoping to find an answer to the problem, the city in 1916 adopted an ordinance requiring cast-iron soil pipe from house to street sewer. The city's chief plumbing inspector reports no record of tree roots penetrating this type of pipe.

According to standard practice, the city contracts for the soil line installation from the street sewer to the property boundary, while the owner contracts for the remainder. On installations preceding the 1916 ordinance, the owner must assume the cost of removing roots from a soil line if the pipe is non-metallic.

It is claimed that the usual lead-oakum joint used with cast-iron pipe also has the advantage of flexing without breaking when settling or heaving of the soil during heavy rains or frost pushes the pipe out of line.

* Faust, S. D., "Syndets in Sewage Can Be Measured." *Water and Sew. Works*, **100**, 6, 252 (1953).

Tomato Seed Saga

If you've ever been at a loss for a good description of what happens—or doesn't happen—to tomato seeds during sewage treatment, the following may help in framing your next reply to that universal question. The excerpt is from an article on "Wealth from Waste," by Y. N. Kotwal, in a recent issue of *Plumbing and Sanitation* (India).

". . . an extra-ordinary example of the resistance and wonderful capabilities of apparently tiny looking objects one is prone to despise. The sewage brings with it all sorts of vegetable and weed seeds, but digestion kills off all of them with the only exception of tomato seeds. . . The insignificant tomato seed, after giving a slip to the pursuing human teeth in the mouth, has survived the digestion in the human stomach. Nature throws it out and it then flows unpurturbed in the dark underworld of the sewers once again to emerge in the light at the Purification plant, where it again dives in the darkness, goes through the preliminary and Consolidation Tanks, receives serious hammering in the pump, stays 21 days in the Digestion Tank in complete darkness and unfriendly atmosphere fighting with myriads of enemies, and when it comes out in the daylight in the liquid digested sludge it lies in the sand and dried sludge waiting for the first friendly rain to sprout up as a healthy member of the plant kingdom to propagate its species. What wonderful resistance, wiliness and tenacity to survive only for human food. . ."

Mr. Kotwal's point was well put, however, as he used this flowery language to urge the same "never-say-die" spirit in technicians seeking the answers to sanitation problems of his country!

LINCOLN ARC WELDING AWARD PROGRAM

The James F. Lincoln Arc Welding Foundation of Cleveland, Ohio, has announced a $13,500 Arc Welding Award Program for selected business and service establishments. Men or women engaged in any of the selected businesses may be awarded as much as $1,000 for written descriptions of the use or possible use of arc welding in the maintenance, operation, or services performed by the business. A total of 191 awards will be made to individuals in the 40 different types of eligible non-industrial businesses and service establishments, among which are included water and sewage works.

None of the selected businesses or establishments is in a metal fabrication field where welding is generally used. These have been eliminated to limit the program to people who have similar opportunity for using welding. Closing date for entries is May 31, 1954.

An illustrated booklet of rules for the program is available from The James F. Lincoln Arc Welding Foundation, Cleveland 17, Ohio.

Federation Affairs

TWENTY-SIXTH ANNUAL MEETING PREVIEW

Bayfront Auditorium, Miami, Fla., October 13–16, 1953

*

IN CONJUNCTION WITH
THE FLORIDA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

*

THE OFFICIAL PROGRAM

MONDAY, OCTOBER 12

Afternoon

Early Registration—Bayfront Auditorium.
Inspection of Exhibits—Bayfront Auditorium.

TUESDAY, OCTOBER 13

Morning

Registration—Bayfront Auditorium.
Inspection of Exhibits—Bayfront Auditorium.
Twenty-Sixth Annual Meeting Called to Order—Bayfront Auditorium.
President E. Sherman Chase
Invocation
Reports of Federation Officers
Virginia Key Sewage Treatment Plant for Miami.
John S. Bethel, Jr., Consulting Engineer, Metcalf and Eddy, Boston, Mass.
Discussion: Hon. Chelsie J. Senerchia, Mayor, Miami, Fla.

Afternoon

Sewage Service for Metropolitan Fringe Areas
M. H. Klegerman, Consulting Engineer, Alexander Potter Associates, New York, N. Y.
Discussion: Charles R. Velzy, Consulting Engineer, Nussbaumer, Clarke and Velzy, New York, N. Y.
Recent Developments in Sewer Pipe Jointing Materials
Donald F. Deakin, Atlas Mineral Products Co., Mertztown, Pa.
Discussion: Morris N. Lipp, City Engineer, Miami, Fla.
Sewer Maintenance Practice in Los Angeles
W. A. Schneider, Waste Disposal Engineer, Bureau of Maintenance and Sanitation, Los Angeles, Calif.
Discussion: To Be Arranged.
Sewage Plant Design Criteria for the Semi-Tropics
Thomas deS. Furman, Assistant Professor of Civil Engineering, University of Florida, Gainesville, Fla.
Discussion: George S. Russell, Consulting Engineer, St. Louis, Mo.

Evening

FAMILY NIGHT ENTERTAINMENT—Bayfront Auditorium.

WEDNESDAY, OCTOBER 14

Morning

Scum Control in Sludge Digestion

Ralph E. Fuhrman, Deputy Director of Sanitary Engineering, District of Columbia, Washington, D. C.

Discussion: L. E. Langdon, Pacific Flush Tank Co., Chicago, Ill.

Studies of Accelerated Digestion of Sewage Sludge

Philip F. Morgan, Professor of Civil Engineering, University of Iowa, Iowa City, Iowa.

Discussion: James H. Blodgett, Superintendent, Sewage Treatment Plant, Columbus, Ohio.

Higher Digester Solids Loading Rates With Concentrated Primary and Activated Sludge

W. N. Torpey, Sanitary Engineer, Department of Public Works, New York, N. Y.

Discussion: R. S. Rankin, Engineer, The Dorr Co., Stamford, Conn.

Basic Factors of Oxygen Transfer in Aeration Systems

Arthur T. Ippen and Charles E. Carver, Jr., Research Assistants, Department of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Discussion: W. E. Dobbins, Associate Professor of Sanitary Engineering, New York University, New York, N. Y.

Noon

FEDERATION LUNCHEON—Biscayne Terrace Hotel.

Sanitation Problems in Florida

Dr. Wilson T. Sowder, State Health Officer, Florida State Board of Health.

Afternoon

The Future of Industrial Wastes Treatment

Hayse H. Black, Chief Sanitary Engineer, Industrial Wastes Section, USPHS Environmental Health Center, Cincinnati, Ohio.

Discussion: F. W. Mohlman, Director, Division of Laboratories, Sanitary District of Chicago, Ill.

Determining Risks of Toxic Substances in Water

Edward J. Cleary, Executive Director and Chief Engineer, Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio.

Discussion: George E. Burdick, State Biologist, New York State Conservation Department, Albany, N. Y.

Factors Involved in Lake Disposal of Effluents

Clair N. Sawyer, Professor of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Discussion: Harold B. Gotaas, Professor of Sanitary Engineering, University of California, Berkeley, Calif.; and James B. Lackey, Professor of Sanitary Science, University of Florida, Gainesville, Fla.

Preventive Maintenance

Francis A. Sanders, Lieutenant-Colonel, USAF Institute of Technology, Wright-Patterson Air Force Base, Ohio.

Discussion: Kerwin L. Mick, Superintendent and Chief Engineer, Minneapolis-St. Paul (Minn.) Sanitary District.

THURSDAY, OCTOBER 15

Morning

Treatment of Complex Metal Finishing Wastes
K. S. Watson, Wastes Engineer, General Electric Co., Schenectady, N. Y.
Discussion: William S. Wise, Chief Engineer, State Water Commission, Hartford, Conn.

Disposal of Steel Production Wastes at the Fairless Works
G. A. Howell, Assistant to Chief Engineer, U. S. Steel Co., Pittsburgh, Pa.
Discussion: Grant A. Pettit, Industrial Waste Engineer, Armco Steel Corp., Middletown, Ohio.

Water and Waste in the Woodpulp Industry
Harold R. Murdock, Chemical Engineer, Robert and Co. Assoc., Atlanta, Ga.
Discussion: Harry W. Gehm, Jr., Technical Adviser, National Council for Stream Improvement, New York, N. Y.

Crop Irrigation for Sewage Effluent Disposal
L. E. Engelbert and E. Truog, Department of Soils, College of Agriculture, University of Wisconsin.
Discussion: R. A. Webster, Superintendent, Wastes Treatment Plant, Seabrook Farms Co., Seabrook, N. J.

Afternoon

INDUSTRIAL WASTES FORUM
Don E. Bloodgood, Leader
Criteria for Stream Usage
Water Dilution Factors for Industrial Wastes
Natural Purification of Streams
Steam Standards *vs.* Effluent Standards

Evening

ANNUAL FEDERATION DINNER—Bayfront Auditorium.
DANCE—Biscayne Terrace Hotel.

FRIDAY, OCTOBER 16

Morning

THE OPERATORS' FORUM
M. E. Dawkins, Leader
Manpower Requirements for Operation
Control of Frothing
Landscaping and Care of Plant Grounds
Training Programs for Plant Personnel

TECHNICAL PROGRAM COMMENTS

The Program Committee, under the chairmanship of F. W. Gilcreas, has developed a technical program designed to appeal to those interested in all phases of Federation activity. Subjects of wide diversity and timely interest make the meeting a primary source of technical information for all.

As so successfully carried out in 1952, the forum sessions for operators and industrial wastes personnel will be held at different times. The Operators' Forum will occupy its usual period on the morning of the last day, Friday, October 16, with the Industrial Wastes Forum coming on Thursday afternoon, October 15. This is intended to give added emphasis to both popular features by allowing attendance at both for those who so desire.

All technical sessions will be held in the Bayfront Park Auditorium, which is air-conditioned.

The program has been planned so as to conflict as little as possible with the meeting of the Florida Section, AWWA, which is being held in Miami, October 12–13.

SOCIAL FUNCTIONS

An informal Family Night Entertainment on Tuesday evening will provide a full program of professional talent. Here is fun for all and a good opportunity to greet old friends and meet new ones.

The Annual Federation Luncheon, to be held Wednesday noon in the Starlight and Panorama Rooms of the Biscayne Terrace Hotel, will be a featured event of the meeting. The speaker at the luncheon will be Dr. Wilson T. Sowder, Director of the Florida State Health Department, whose subject will be "Sanitation Problems in Florida."

No meal or entertainment events are scheduled for Wednesday evening, so that all may dine and seek entertainment according to individual choice. The Local Host Committee will be prepared to furnish this type of information for all who seek it.

The highlight of the meeting will be the ever-popular Annual Dinner on Thursday evening. This event, to be held in the air-conditioned Bayfront Auditorium, will feature the presentation of the annual Federation awards and honors. Dress will be optional, with dancing to an excellent orchestra following in the Starlight and Panorama Rooms of the Biscayne Terrace Hotel.

The Business Luncheon of the Florida Sewage and Industrial Wastes Association is scheduled for 12:15 P.M. on Tuesday, October 13, in the Flagler Ballroom of the McAllister Hotel. Guests will be welcome; tickets are priced at $2.50.

A dinner meeting of the Loyal Order of the Boar also is scheduled at the Everglades Hotel at 6:30 P.M. on Wednesday, October 14, Col. W. A. Hardenbergh and J. J. Gilbert are in charge of arrangements.

LADIES' ENTERTAINMENT

Special entertainment for the ladies will emphasize the sightseeing opportunities of the gateway city of the Caribbean and this winter playground of so many Americans. These events will be in addition to those scheduled for Tuesday and Thursday evenings, as outlined under "Social Functions."

Tuesday afternoon will feature relaxation, refreshment, and a chance to meet and greet friends at a Get-Aquainted Tea at the Biscayne Terrace Hotel.

On Wednesday afternoon a bus tour will feature the sights of Miami, fabulous Miami Beach, Coral Gables, the University of Miami, Miami Springs, and other points of interest. Included will be a visit to the Parrot Jungle, a tropical bird haven in natural surroundings.

Thursday morning will be devoted to a restful two-hour cruise on Biscayne Bay, affording unusual views of Miami, Miami Beach, and the residences on the man-made islands of Biscayne Bay's "Millionaire Row."

POST-CONVENTION HAVANA TOUR

For those who wish to extend their stay for a visit to Havana, Cuba, arrangements have been made for an all-expense tour. The cruise may be made by steamer at $95.30 or by air at $93.80, both prices per person and including taxes.

The *S. S. Florida* will depart from Miami at 6:00 P.M. on Friday, October 16, arriving at Havana the next morning. The group will stay at the Hotel Nacional De Cuba. Tours will include the entire city and a country trip, with visits to the Capitol Building, La Merced Cathedral, a cigar factory, an alligator factory, Colon Cemetery, a rum distillery, the Chateau Madrid Estate, and a perfume factory. Also included is a dinner at the Tropicana night club, with entertainment at a rhumba cabaret and "Sloppy Joe's." The steamer cruise will leave Havana on Sunday evening for arrival at Miami at 8:00 A.M. on Monday, October 19. The plane tour will return to Miami Sunday evening.

Rates include all transportation, meals on steamer, double occupancy hotel room, entrance fees, guide services, dinner at the Tropicana, and luncheon at the Chateau Madrid Estate.

In making advance reservations, furnish first and last name of each passenger, place and date of birth, and cruise desired. A deposit of $5.00 per person is required to hold reservations. For further particulars or to place reservations write Mitchell's Tours, Inc., 59 S. E. Eighth St., Miami 36, Florida.

MANUFACTURERS' EXHIBIT

Improved and new equipment and supplies will be displayed at the meeting by members of the Water and Sewage Works Manufacturers' Association in a setting that may well make this the most memorable of many such exhibits. Some 36 manufacturers and suppliers had been allocated all available exhibit space by early August. In addition to seeing the latest in equipment in the sewage and industrial wastes treatment field, those attending the meeting will be able to get first-hand technical data from informed company representatives.

The following companies have scheduled representation in the exhibit:

American Car & Foundry Company
American City Magazine
American Well Works
Armco Drainage & Metal Products, Inc.
Builders-Providence, Inc.
Ralph B. Carter Company
Chain Belt Company
Chicago Pump Company
Combustion Engineering, Inc.
The Dorr Company
Engineering News-Record
Fischer & Porter Company
The Foxboro Company
General Electric Company
General Laboratory Supply Company
Hardinge Company
Inertol Company, Inc.
Infilco Incorporated.
The Jeffrey Manufacturing Company
Johns-Manville
Lakeside Engineering Corp.
Link-Belt Company
Lock Joint Pipe Company
Nichols Engineering & Research Corp.
Omega Machine Company
Pacific Flush Tank Company
The Preload Company, Inc.
Price Brothers Company
Public Works Magazine
Simplex Valve & Meter Company
The Vapor Recovery Systems Company
Walker Process Equipment, Inc.
Wallace & Tiernan Company, Inc.
Wastes Engineering
Water & Sewage Works
Yeomans Brothers Company

REGISTRATION INFORMATION

Registration facilities will be located in the Bayfront Auditorium at the entrance to the exhibit hall. The desk will be open for early arrivals on Monday afternoon, October 12, from 1:00 to 5:00 P.M. On Tuesday, Wednesday, and Thursday the desk will be open from 8:30 A.M. to 5:00 P.M.

Men's registration at $11.00 will include technical session privileges, the Family Night Entertainment on Tuesday evening, and the Annual Dinner and dance following on Thursday evening. Tickets for the Annual Federation Luncheon on Wednesday will be sold separately at $2.50 each.

Ladies' registration at $11.00 will cover the Family Night Entertainment, the Annual Dinner, the dance, and all special events for the ladies.

In separate tickets, the registration fee (required for admission to technical sessions) is $6.00 and the Annual Dinner is $5.00.

Early registration—before 5:00 P.M. on Monday—will avoid the rush on Tuesday morning and also allow a leisurely visit to the manufacturers' exhibit.

HOTEL ARRANGEMENTS

Liberal allocations of rooms have been reserved for Federation members and guests by five hotels fronting Bayfront Park, locale of the meeting. Reservations should be placed early, however, as the room commitments expire before October 1.

Requests for reservations may be made on the forms provided with the advance notice of the meeting sent in July to all Journal subscribers, or directly to the FSIWA Housing Committee, 320 N. Fifth St., Miami, Fla., indicating first, second, and third choices from the following list:

Hotel	Single (per room)	Double (per room)	Triple (per room)	Suites
Alcazar	$4–$5	$5–$8	$10	$12–$14
Biscayne Terrace	—	$8–$12	—	$20–$24
Columbus	$6	$8–$10	$12	$20
Everglades	$4–$6	$6–$9	—	$14–$15
McAllister	$4–$6	$6–$9	$10	$25

LOCAL ARRANGEMENTS COMMITTEE

The Local Arrangements Committee, under the general chairmanship of C. F. Wertz, Research Engineer of the Miami Department of Water and Sewage, is composed of the chairmen of the following sub-committees:

Registration Committee: D. P. Schiesswohl, chairman; A. Murphy, G. T. Lohmeyer, T. deS. Furman, B. F. Snow, and H. P. Orland.

Finance Committee: J. R. Hoy, chairman; R. Metcalf, and C. E. Fiveash.

Entertainment Committee: A. B. Kononoff, chairman; M. N. Lipp and R. C. Hunderadt.

Ladies Entertainment Committee: N. D. Hoy, chairman; Mrs. C. F. Wertz, Mrs. W. W. Aultman, Mrs. M. H. Connell, Mrs. E. M. Rader, Mrs. J. S. Whitney, Mrs. S. T. Drew, Mrs. B. F. Borden, Mrs. D. B. Lee, and Mrs. J. W. Wakefield.

Local Host Committee: B. F. Borden, chairman; P. Flanagan, F. A. Eidsness, W. J. Parks, D. B. Lee, W. W. Aultman, and J. E. Kiker, Jr.

Hotel Arrangements Committee: J. A. Stevens, chairman; Ellis Phelps, C. H. Carothers, and J. W. Greenleaf, Jr.

Reviews and Abstracts*

Heat Treatment as an Aid to Sludge Dewatering—Ten Years' Full-Scale Operation. By C. Lumb. *Jour. and Proc.*, Inst. Sew. Purif. (Brit.), Part 1, 5 (1951).

The potential advantages of some mechanical sludge dewatering process over atmospheric drying include non-dependence on uncontrollable climatic conditions, ability to maintain sludge disposal to regular schedule in all seasons of the year, and small land area requirements.

Conditioning of sludge, prior to filtration, has usually been used. This paper describes the operation of a plant at Halifax, England, which, over a 10-year period, has conditioned raw sludge by heating the sludge mixture with live steam, to temperatures from 290° to 370° F. for 0.5 hr. The process, known as the Porteous process, involves the heating of sludge by means of live steam in pressure vessels. Heat exchange apparatus is incorporated for maximum economy.

The installation is designed to handle 25,000 gal. (Imp.) of sludge consisting of humus and activated sludges in the proportion of approximately 5 to 1 dry solids basis, respectively, in an 8-hr. day. Raw sludge is pumped from a 40,000-gal. tank through a heat exchanger into the cooking vessels. The sludge is cooked 45 min. with injections of live steam, at a temperature of 360° F. and a pressure of 150 lb. per sq. in. After cooking, steam pressure evacuates the sludge through the heat exchanger counter-current to raw sludge inflow, thence into elevated storage, where it settles overnight. After settling, 60 per cent of the volume is drawn off as supernatant and returned to the plant influent at a uniform rate over 20 hr. The residue is then dewatered in a filter press, the filtrate being returned to the plant influent and the filter cake being used as a fuel or as a fertilizer after further drying.

Relative speeds of filtration of sludges conditioned in different ways are as follows:

Conditioning Agent	Primary Sludge	Sec. Sludge [1]
None	30	1
Sulfuric acid [2]	100	2
Aluminum sulfate [3]	200	10
Ferric sulfate [3]	300	15
Ferric chloride [3]	400	20
Lime [3]	1,000	80
Heat treatment [4]	6,000	1,000

[1] Mixed humus and activated sludge.
[2] At optimum H value.
[3] At optimum dosage.
[4] ½ hr. at 360°F.

The average moisture content of the raw sludge is 95.1 per cent, of the thickened sludge after heat treatment and decantation, 89.9 per cent, and of the cake from the filters, 48.0 per cent.

Average analysis of the pressed filter cake, on a dry basis, is: organic and volatile matter, 51.2 per cent; nitrogen, as N, −2.26 per cent; phosphoric acid, as P_2O_5, 5.14 per cent; and potash, as K_2O, 0.27 per cent.

The over-all heat recovery has been more than 75 per cent, even though continuous operation was not practiced. Operating costs compare favorably with other sludge disposal methods, while the capital cost, for equal duty, would appear to be less than that of heated digestion plus drying beds.

There are no odor nuisances and with the sale of sludge cake, disposal is complete.

K. W. Cosens

The Behavior and Distribution of the Larger Worms in Trickling Filters. By R. J. Terry. *Jour. and Proc.*, Inst. Sew. Purif. (Brit.), Part 1, 16 (1951).

The two earthworms found commonly in trickling filters in England are *L. rubel-*

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

lus and *E. foetida*. The first worm produces 90 offspring per year, whereas the latter averages about 25 to 30. The earthworms seemed to be more commonly found in the filters having relatively small media and inhabited zones near the surface but below a depth of 2 in. from the top of the media.

The worms are nocturnal in habit and are repulsed by light. Their numbers in the filter media varied considerably from one season to another, maximum population being from 3 to 6 times the minimum population, with counts frequently showing filter populations to be 10 to 80 times as great as rich earth populations.

Laboratory-size experimental filters were set up and an attempt was made to eliminate all variables except that 50 adult *E. foetida* worms were placed on one filter, the other receiving none. Over a 4-month period the filter with the worms maintained a 20 per cent greater ability to remove organic loads as determined by the oxygen absorption test than did the filter without worms.

It was reported that *Haemopsis sanguisuga*, the horse leech, was found frequently in trickling filters, but not in numbers great enough to exert either a harmful or beneficial effect on filter performance.

It was noted that the effects of the earthworm are beneficial to efficient filter operation by mechanically scouring the beds and increasing bed efficiency. New filters could be seeded with the worms to facilitate their growth at an early date within the filter media.

K. W. COSENS

Dewatering of Sewage Sludge by Coagulation and Vacuum Filtration. Part III. Experiments with a Semi-Scale Dorr-Oliver Vacuum Filter, Using Chlorinated Copperas as the Coagulant. BY C. JEPSON AND G. GREENE. *Jour. and Proc.*, Inst. Sew. Purif. (Brit.), Part 1, 26 (1951).

A semi-scale Dorr-Oliver vacuum filter was set up to filter sludges treated by two types of coagulants. In some cases elutriation was used, in others it was omitted. Digested sludge and activated sludges were both tested. Because ferric chloride was no longer available in the desired quantities needed for sludge conditioning, tests were run using chlorinated copperas and results were compared with the results obtained using ferric chloride.

Filtration of Manchester activated sludge with chlorinated copperas as a coagulant gave a cake with a moisture content of 83.5 to 89.8 per cent. The output of cake averaged 0.74 lb. dry solids per square foot per hour, with an average chlorinated copperas demand of 19.1 per cent.

Aeration of activated sludge prior to filtration had little influence on output but reduced the amount of chlorinated copperas required for conditioning.

Filtration of elutriated digested sludge produced a cake with a moisture content of 72 to 75.9 per cent, an output of 1.35 to 1.72 lb. dry solids per square foot per hour, and an average chlorinated copperas demand of 13.0 per cent.

Compared with ferric chloride, chlorinated copperas has two main disadvantages: more of it is required to produce the same result, and the rate of filtration of the coagulated sludge is slower. It was found that, despite these drawbacks, it was cheaper to use chlorinated copperas, which gave practically the same end product.

K. W. COSENS

Sterilization of Sewage Sludges. Part I. A Review of the Literature Pertaining to the Occurrence and Viability of Parasitic Ova and Cysts in Sewage, with Special Reference to *Ascaris lumbricoides*. BY P. KELLER. *Jour. and Proc.*, Inst. Sew. Purif. (Brit.), Part 1, 92 (1951).

It is reported that during World War II in Darmstadt, Germany, 80 to 90 per cent of the populace were infected with *Ascaris lumbricoides*, the human round worm, which was traceable to the sewage plant or to sewage irrigation farms. Sedimentation, properly applied, supposedly removes the cysts from the supernatant.

In South Africa, the sewage sludges were to be used for fertilizer, so this work was started to learn more of the occurrence and life of the cysts in sewage.

A search of the literature was made and reported under the following headings:

1. Life cycle of *Ascaris lumbricoides*.
2. Power of resistance.
3. Temperature and oxygen requirements.
4. Thermal death point.
5. Moisture requirements.

6. Resistance to chemical agents.
7. Influence of sewage treatment.
8. Hatching of *Ascaris* eggs in culture.

Part II. The Influence of Heat Treatment on the Ova of *Ascaris lumbricoides* in Sewage. By P. Keller. *Jour. and Proc.*, Inst. Sew. Purif. (Brit.), Part 1, 100 (1951).

Thermophilic digestion of sewage sludge on a laboratory scale has been tested experimentally as a means of destroying or inactivating the ova of parasitic worms and the cysts of amoebae parasitic to man, which are usually found in sewage sludge during practically all stages of treatment for disposal. It has been found that thermophilic digestion for a minimum period of 24 hr. destroys all parasitic ova and cysts.

Since thermophilic digestion as such, however, entails certain disadvantages, the effect of heat treatment on sewage sludge after digestion at mesophilic temperatures has been investigated. It has been found that prolonged exposure of sewage sludges to a temperature of 37°C. completely inactivates the ova of *Ascaris lumbricoides*, which served as the index organism. The process, however, is impracticable, since the period of time required for complete destruction would be too long.

It has been found that if normally digested sewage sludge or raw sewage sludge is heated for 2 hr. at 55°C., complete destruction of all parasitic ova and cysts usually met with in sewage occurs. Heating sewage sludges to higher temperatures decreases the period of exposure necessary, but decreases at the same time the ease of filtration of the sludge and imparts an objectionable odor to it, which makes the use of drying beds or open storgage of the liquid sludge impossible.

The effect of the Porteous process on the ova of *A. lumbricoides* has also been investigated, but incorporation of the process into existing conventional sewage treatment does not appear to be warranted for various reasons. The influence of heat treatment on pathogenic bacteria and viruses has not been investigated.

K. W. Cosens

Treatment of Settled Sewage in Percolating Filters: Experiments at Minworth, Birmingham, 1947–1950. By T. G. Tomilinson and H. Hall. *Jour. and Proc.*, Inst. Sew. Purif. (Brit.), Part 1, 110 (1951).

Comparison of results obtained on full-scale filters by three processes of biological filtration, or three different methods of circulation, at the same average rate of 150 g.p.d. (Imp.) per cubic yard of media shows that alternating double filtration gave effluents having lower B.O.D. and oxygen absorbed values than filtration with recirculation of an equal volume of effluent, or filtration of effluent from a bio-flocculation plant. On the average, nitrification was about the same in the two recirculation processes, but alternating double filtration maintained filters in better condition during the first four months of the year. Only a small amount of film accumulated in the filter that treated effluent from the bio-flocculation plant.

The effects of slowing down the rate of revolution of distributors from 1 revolution in 1.4 min. to 1 revolution in 8 min. on the performance of alternating double filters operated at an average rate of 150 g.p.d. per cubic yard were to improve the quality of the effluent and to improve the condition of the filters during winter.

Small-scale filters operated at 240 g.p.d. per cubic yard by double filtration, alternating double filtration, and filtration with recirculation of effluent gave final effluents of about the same quality. The condition of the filters operated by the last two processes was always satisfactory; a very heavy surface growth of fungus developed on the surface of the primary filter of the pair operated as double filters without alternation.

K. W. Cosens

BOOKS, REPORTS, AND PAMPHLETS

Fifth Annual Report. New England Interstate Water Poll. Control Comm., Boston, Mass. 32 pp. (1952).

An Analysis of Refuse Collection and Sanitary Landfill Disposal. Tech. Bull. No. 8, Series 37, Univ. of California, 1301 South 46th St., Richmond 4, Calif. 133 pp. Price, $1.50 (Dec., 1952).

Lithographed on stone for U. S. Pipe and Foundry Co. by John A. Noble, A. N. A.

THIS ILLUSTRATION shows the laying of cast iron pipe in the business section of a small town, which could be for water, gas or sewerage service. Such a situation calls for a pipe with proved long life to be placed beneath the costly permanent pavement. Whether in the business district, residential area or the country, cast iron pipe has established an enviable record of low cost per service year.

We are in an excellent position to furnish your requirements for cast iron pipe, either centrifugally cast in sizes 2- to 24-inch or pit cast for larger sizes—all of which are produced under rigid quality controls and in accordance with standard specifications.

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Proceedings of Member Associations

NORTH CAROLINA SEWAGE AND INDUSTRIAL WASTE ASSOCIATION

The 32nd Annual Joint Meeting of the North Carolina Sewage and Industrial Waste Association and the North Carolina Section, AWWA, was held at the Skyland Hotel, Hendersonville, N. C., on November 10–12, 1952. The total registration of 261, including 37 ladies, exceeded all previous registrations except those for 1928 and 1929.

Of interest to those in the waste treatment field were panel discussions on "Home-Made Alarms and Controls," "Selection and Use of Protective Coatings," "Sewer Use Ordinance," and "Maintenance of Sewage Collection Systems." Other papers of interest included:

"Forecasting North Carolina's Industrial and Community Growth," by Brandon P. Hodges, State Treasurer.

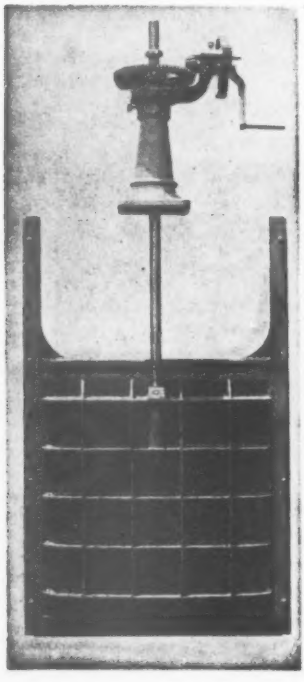
"Planning Water and Sewage Facilities for Future Growth," by H. E. Beckwith, Pitometer Co., and P. D. Davis, Consulting Engineer, Durham.

"A Proposal for Solving Water and Sewage Needs for Suburban Areas," by J. T. Ramseur, Health Officer, and W. N. Long, Chief Sanitary Engineer, Gaston County Health Dept.

"The Use of Tonnage Oxygen in Sewage Treatment," by D. A. Okun, Associate Professor of Sanitary Engineering, University of North Carolina.

An inspection trip was made to the Ecusta Paper Corp. plant at Pisgah Forest, N. C.

(*Continued on page 364a*)



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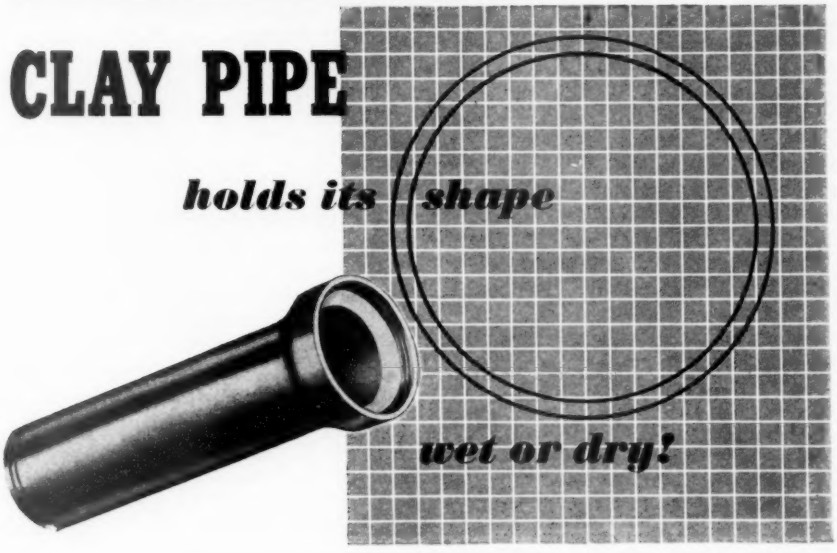

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At the Annual Banquet, the Federation's Arthur Sidney Bedell Award was presented to H. G. Baity.

At the Annual Business Meeting, a voluntary plan for examination and certification of sewage and waste treatment works operators was adopted and implemented. Officers were elected for the ensuing year as follows:

Chairman: J. L. Greenlee, Charlotte.
Vice-Chairman: W. B. Snow, Durham.
Secretary-Treasurer: E. C. Hubbard, Raleigh.

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CENTRAL STATES SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

The 26th Annual Conference of the Central States Sewage and Industrial Wastes Association was held at the Pere Marquette Hotel, Peoria, Ill., June 3–5, 1953. Registration for the meeting totaled 174, including 24 ladies.

Papers presented at the meeting were as follows:

"Treatment of Garbage at an Activated Sludge Sewage Treatment Plant," by W. E. Ross, City Engineer, Richmond, Ind.

"Oxygen Demand—A Review," by A. M. Buswell, Chief, and Irene Van Meter, State Water Survey, Urbana, Ill.

"Treatment of Domestic and Industrial Waste at Fond du Lac, Wisconsin," by Bruno J. Hartman, Consulting Engineer, Sheboygan, Wis.

"Program of Elimination of Clear Water and Operation of Treatment Plant Under Adverse Flow Conditions," by Ray D. Leary, Chief Engineer and General Manager, Milwaukee Sewerage Commission, Milwaukee, Wis.

"The Sources of Waste Within the

(*Continued on page 366a*)

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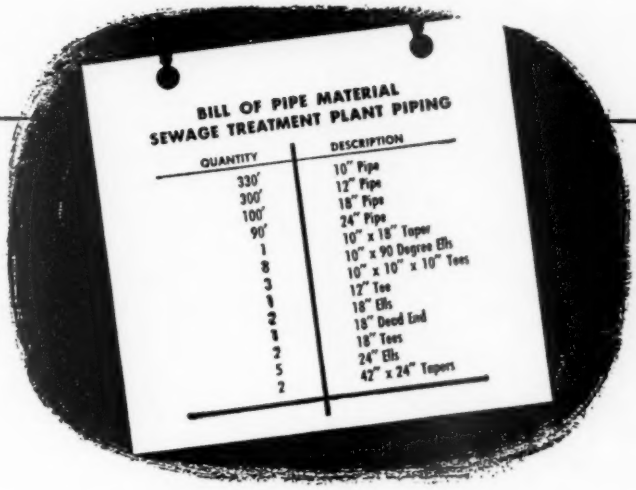

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Brewery," by Fred Hale, Assistant Chief Chemist, Pabst Brewing Company, Peoria, Ill.

"Grain Distillery Feeds and Wastes —A Review," by C. S. Boruff, Technical Director, and Russell K. Blaine, Chemist, Hiram Walker & Sons, Inc., Peoria, Ill.

On the evening of June 3 an enjoyable buffet dinner and social hour was held at the Pabst brewery, Peoria Heights, in conjunction with an inspection of the brewery.

The afternoon session on June 4 consisted of the annual business meeting, followed by inspection trips to the Hiram Walker and Sons distillery and feed house waste recovery system, and the sewage treatment plant of the Greater Peoria Sanitary District.

At the annual banquet, held that evening, George J. Schroepfer was awarded the Association's Gus Radebaugh Award for the best paper of 1952, and Don E. Bloodgood was presented the Federation's Arthur Sidney Bedell Award. A social hour preceded the annual banquet and another social hour and entertainment followed it. Both were sponsored by members of the Water and Sewage Works Manufacturers' Association.

The morning session on June 5 consisted of an "Operators' Breakfast," in which open discussion on plant operation problems was stimulated and guided by a panel.

Officers elected for 1953–54 were:

President: E. Hurwitz, Chicago, Ill.
1st Vice-President: O. J. Muegge, Madison, Wis.
2nd Vice-President: A. J. Duvall, St. Paul, Minn.
3rd Vice-President: W. E. Ross, Richmond, Ind.
Secretary-Treasurer: A. P. Troemper, Springfield, Ill.

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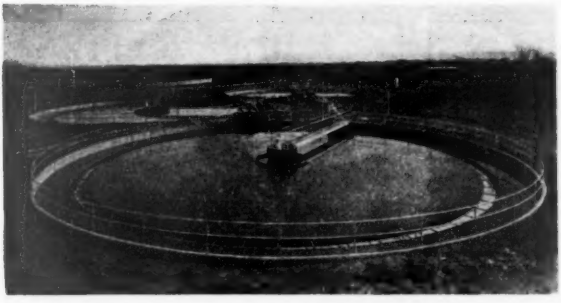

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(Continued through page 373a)

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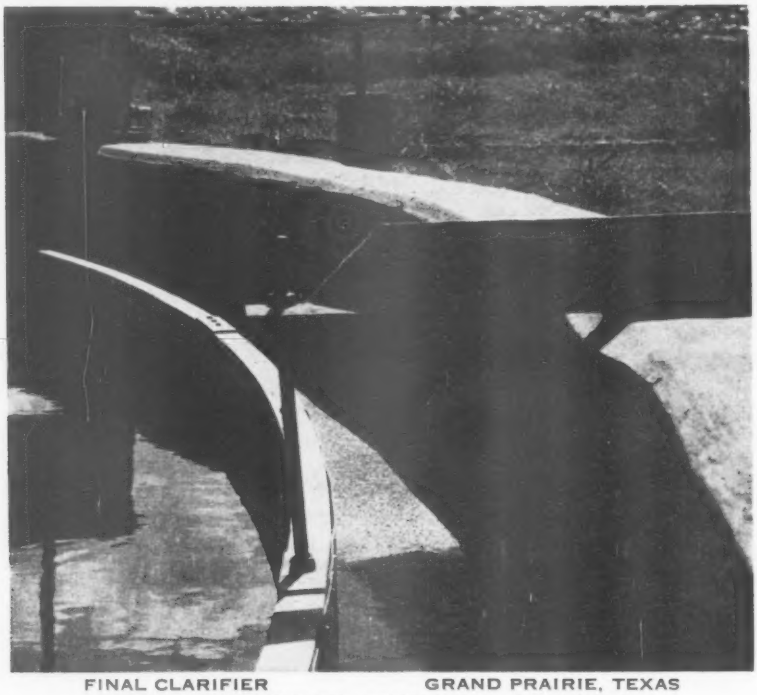

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INDEX TO ADVERTISERS

	Page
American Aniline Products, Incorporated	339a
American Brass Company, The	341a
American Car and Foundry Company	329a
American Cast Iron Pipe Company	340a
American Well Works	342a
Armco Drainage and Metal Products, Incorporated	365a
Bailey Meter Company	344a
Carborundum Company, The	348a
Chain Belt Company	356a, 357a
Chapman Valve Manufacturing Company	346a
Chicago Pump Company	Inside front cover, 321a
Clow, James B., and Sons (Iowa Valve)	338a
Combustion Engineering, Incorporated (Flash Dryer Division)	353a
Dorr Company, The	Inside back cover, 360a
Everson Manufacturing Corporation	336a
Fairbanks, Morse and Company	354a
Flexible Sewer-Rod Equipment Company	376a
Foxboro Company, The	358a
General American Transportation Corporation (Process Equipment Div.)	345a
General Chemical Division (Allied Chemical and Dye Corp.)	352a
General Electric Company	343a
General Laboratory Supply Company	364a
Infilco Incorporated	335a
Jeffrey Manufacturing Company	337a
Johns-Manville Corporation	355a
Lakeside Engineering Corporation	374a
Link-Belt Company	347a
Lock Joint Pipe Company	334a
National Clay Pipe Manufacturers, Incorporated	363a
Nichols Engineering and Research Corporation	350a
Omega Machine Co.	323a
Pacific Flush Tank Company	330a, 331a
Process Engineers, Incorporated	367a
Rockwell Manufacturing (Nordstrom Valve Division)	332a
Simplex Valve and Meter Company	325a
Snow Irrigation Supply Company	362a
Tnemec Company, Incorporated	366a
United States Pipe and Foundry Company	361a
Vapor Recovery Systems Company	333a
Walker Process Equipment, Incorporated	351a
Wallace and Tiernan Company, Incorporated	Back Cover
Wood Company, R. D.	349a
Worthington Corporation (Public Works Division)	328a
Yeomans Brothers Company	327a

DIRECTORY OF ENGINEERS, pp. 368a–373a

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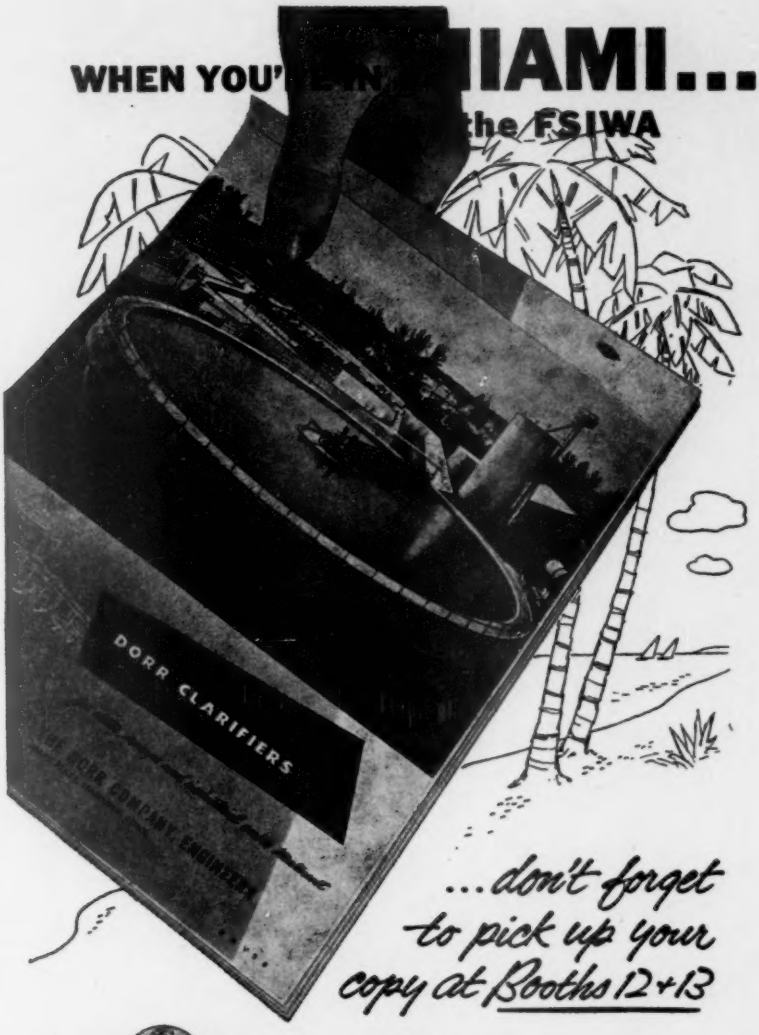

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